# URBAN AGGLOMERATION, INTANGIBLE INPUTS, AND EXTERNALITIES IN A MODEL OF ECONOMIC GROWTH

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# PREFACE

This study was conducted to provide new knowledge pertinent to improving the understanding of the phenomenon of economic growth, and differences in per capita income between countries. Intangible inputs like human and urban capital were found to exert a significant impact on the standard of living. These inputs play a dual role in explaining differences in per capita income by also operating as shifters of the aggregate production function. Furthermore, externalities arise from the geographic concentration of human capital leading to an increase in the productivity and earnings of individual workers when they reside where coworkers are more educated. This reinforces another effect in which knowledge spillovers arise as dynamic urban externalities. The second effect furnishes the basis for considering urban capital a separate input. Unlike other studies, this one finds that human capital plays a dual role as shifter and input. The fixed effects estimator was found to be more appropriate for evaluating differences in income across countries. After accounting for these factors, higher rates of convergence to the steady state are obtained than previously found in the literature.

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# TABLES OF CONTENTS

# LIST OF TABLES

# CHAPTER I

## AN INTRODUCTION

One of the long running discussions in the modern literature on economic growth has revolved around the sources of economic growth and improvements in per capita income in the United States and other industrial countries over the last two centuries. More recently, since the end of WWII, output has grown at an estimated 3.3 percent per year, but labor and capital together have grown by about 2 percent over the same period (Stein and Foss 1995, p.52).

Labor had more capital to work with, which contributes to an increase in productivity, but there is still a big gap to fill to thoroughly explain the sources of economic growth. This gap is relegated to the convenient yet ambiguous category of "total factor productivity". Part of this productivity gap is made up by education and experience. After all, the number of people with high school or college degrees has skyrocketed over the same period, and a more educated labor force is a more productive labor force. Nevertheless, according to Stein and Foss "on the basis of an analysis made by the Bureau of Labor Statistics, it appears that the increased educational attainment of the entire labor force between 1948 and 1990 would account for about one-sixth of the rise in output per hour in the private business sector over the same period" (1995, p54).

These writers add that "*human capital is one form of intangible capital.* Another is the stock of scientific and technological knowledge" (Ibid). This stock of technological and scientific knowledge is the result of diverting resources by private and public institutions to research and development activities, otherwise known as R&D. Many writers believe that R&D expenditures are an important source of economic growth and labor productivity increases (Acs, Audretsch, and Feldman, 1994). The long-run and cumulative nature of R&D activities, however, made it difficult to isolate the role of R&D as a source of productivity growth (Beeson 1993).

Another question has been the role of public and urban infrastructure in the growth of productivity and hence the standard of living. Some economists and politicians have argued that the recent slow growth of public infrastructure was partially responsible for the slowdown in productivity growth. Others have responded that the direction of the causality should be reversed. Higher income caused more spending on infrastructure not the other way around (Stein and Foss 1995, p.60).

Either way, after accounting for the increased capital-labor ratio, the accumulation of human capital, and R & D expenditures, a large part of the increase in productivity growth is still left unexplained.

Of course, an increase in productivity need not translate automatically into an increase in economic growth. In an economic recession, for example, labor is easier to fire in the short-run than capital, and thus it is conceivable that the capital-labor ratio and hence productivity would increase at the same time economic growth for the economy in question recedes. This means that for increases in productivity to become increases in economic growth, the additional condition that the current level of resource employment should not decrease should be imposed.

It is possible for technological improvements to be so labor-enhancing that economic growth could result even if the current level of resource employment declines. This would be plausible for example if one worker with a crane was able to dig holes faster than ten with shovels, even if the other nine become unemployed as a result of introducing the crane. Consequently, modern growth theory assumes that a flexible market system relegates unemployment to the short-run, so that improvements in productivity generate economic growth.

*Internationalizing the Dilemma* :

A coherent basic model to explain economic growth and income per capita differences between countries was laid down by Robert Solow in 1956, but it does not fit the data very well in an empirical baptism of fire. The traditional explanatory variables of saving and population growth rates, although relevant and significant, could not sufficiently and conclusively explain differences in the steady states of income across countries. Furthermore, convergence between countries to a theoretically predicted steady state does not occur. As will be expounded at length later, some tried to fix this problem by incorporating human capital into models of economic growth while others tried alternative econometric techniques, but the problem persisted. In a way, this was the international reflection of the same debate that took place in the United States on the unexplained sources of productivity growth.

This dissertation will show that some of the unexplained sources of productivity increases and hence economic growth in different countries, can be accounted for by the inclusion of intangible inputs like human and urban capital into the existing models of economic growth. Because the relevancy of human capital has been discussed by other writers before, as will be shown in Chapter II, the central contribution of this dissertation will be to explain the theoretical and empirical linkages between urban agglomeration and economic growth, in the context of an expanded model within which the role of intangible inputs in general can be gauged. This dissertation builds upon both published and unpublished work on the relationship between economic development and urbanization by Moomaw and Shatter (1992) and Moomaw and Alwosabi (1996), in which some measure of urbanization was the dependent variable, and on the work of Mankiw, Romer, and Weil (1990) and Nazrul Islam (1995) in the field of economic growth.

Furthermore, many economic and econometric issues arise in the course of the discussion, including the contribution of externalities in economic growth. The discussion is couched in terms of the distinctions Glaeser et al (1992) drew between static and dynamic externalities. Econometrically, a panel data approach will be adopted to capture the country effects that do not show otherwise in the context of an augmented economic growth equation, a topic treated in Chapter V. Chapter IV is devoted to the mathematical derivation of this new augmented growth model, whereas Chapter III introduces the concept of urban capital. Chapter VI evaluates the empirical results, and Chapter VII presents the conclusion in terms of theoretical and practical implications.

In short, among plausible determinants of economic growth, the one most neglected in the literature has been perhaps agglomeration economies arising from urban concentration.

The problem then is to set up the proper context to study the effects of urban concentration on economic growth and vice versa without neglecting the contributions of human capital and externalities, some of which arise from the geographic concentration of human capital itself.

So this study purports to :

1- find and examine the types and the strengths of the linkages between urban agglomeration and economic growth.

2- gauge the role of knowledge spillovers and technological externalities in the growth of cities and economies.

3- compare the results of this model with those of other studies in the fields of economic growth and urban economics.

# CHAPTER II

## A Review of the Problem

In an early contribution Adam Smith in his Inquiry into the Nature and Causes of the Wealth of Nations (1776) elaborated on how free markets, the division of labor, the accumulation of capital, and technological progress were responsible for the wealth and poverty of nations. Afterwards the classical economists highlighted economic growth through most of the 19$^{th}$ Century. The marginal revolution shifted the emphasis to the efficiency question, and then somewhat later the Keynesian revolution highlighted unemployment and related macroeconomic questions. Although Keynesians such as Domar (1946) and Harrod (1948) gave some attention to economic growth, the growth analysis did not receive a substantial treatment until the 1950s.

In 1956 Robert Solow published his seminal article "A Contribution to the Theory of Economic Growth", in which he laid down the basis of a modern neoclassical theory of economic growth that could explain cross-country differences in per capita income. In that model differences in the standard of living across countries hark back to differences in the respective saving and population growth rates of those countries. Thus, a higher savings rate, holding everything else constant, is supposed to increase per capita income, whereas a higher population growth rate would cause per income to decrease.

Hence Solow (and Trevor Swan) applied the Ricardian Law of Diminishing Returns to this modern neoclassical model of growth to generate a group of basic propositions about economic growth:

1) Saving is channeled through money markets into investment, which is defined as making goods that can be used in to produce other goods and services. Typically, investment indicates building physical assets of different kinds.
2) A higher saving rate increases income more than a lower saving rate. More saving means more capital accumulation which means more output. Yet a higher population growth rate means that even with more output each person would have less and less output. The standard of living is the result of the balance between those two opposing forces.
3) But physical capital like all other inputs is subject to the law of diminishing returns. Beyond a certain point, each additional injection of that input yields a smaller contribution than the preceding one. That is why output increases at a decreasing rate until the growth rate of output per worker becomes in the limit equal to zero.
4) That tendency for output to grow at a decreasing rate can be counteracted with technological progress which has the effect of shifting the production function of an economy up.

5) Barring technological progress, which is presumed to permeate most countries at more or less the same rate, diminishing returns to capital implies that if you have less capital per worker to begin with, your marginal product from the last unit of capital in use is higher than the marginal product from the last unit in use if you have more capital.
6) Since rich countries have more capital per worker than poorer countries, all the above implies that poor countries should grow faster than rich countries, because the rate of return on their last unit of capital in use is necessarily higher.
7) Over the long-run this means that there will be convergence. Poor countries will catch up with rich countries as the latter grow at a slower rate and the former at a faster rate.

*Empirical Failure:*

In spite of the fact that the theory delineated above seemed to fit the growth experience of the United States quite well as Edward Denison (1962) demonstrated, internationally the data refute some of the above implications: (a) poor countries do not grow faster than rich ones, (b) there is no apparent general tendency for convergence.

The growth rate of rich countries has slowed somewhat since the 1970s, from a little less than an annual 4 percent to a little more than an annual 2 percent (Barro & Sala-I-Martin 1995), providing general support for the diminishing returns aspect of the model. There was not however a concomitant and countervailing increase in the growth rate of poor countries. In fact, there was no discernible inverse statistical association for most countries between their growth rate between 1960-85 and their initial base per capita income in 1960 at all. Unfortunately, the opposite may have seemed to be true (Ibid).

Although it did not explain all aspects of economic growth as it was supposed to, growth economists relied on the neoclassical model for the next few decades until the late 1980s when the unresolved enigma of economic growth was ripped wide open again by the dissecting criticisms of disbelievers. Better data among other things added fuel to the fire. Nazrul Islam commented that "one of the reasons for the recent surge in work on growth empirics has been the availability of the Summers-Heston [1988] data set" (1995, pp. 1138-1139).

Either way there was now a new wave of anti-mainstream growth theories summarily dubbed as "endogenous growth theories". Paul Romer (1987, 1989) spawned some of the most prominent among these, arguing for the end of the era of diminishing returns in capital. If each additional unit of capital contributed more rather than less to output, i.e., if there was increasing returns or constant returns to capital, convergence would be unlikely, and the new theory would provide an explanation for the failure of economies to converge.

Furthermore, "persistence effects" were detected by King and Rebelo (1989) in which convergence was empirically replaced with divergence. The rich and the poor countries here grow farther apart due to the significant positive effect of their lagged dependent variables, i.e., the standard of living in the preceding period, not due to differences in technological progress or the institutional framework.

In 1986, Paul Romer presented a fully specified model in which growth rates can be increasing over time. “Knowledge is assumed to be an input in production that has increasing marginal productivity”(Romer 1986, p.1002). Romer then proceeds to present empirical evidence in support of his model.

In the same vein, Robert Lucas (1990) presented a model suggesting that taking the positive externalities of human capital into consideration would practically wipe out the rate of return differentials on capital between very rich and very poor countries and would therefore eliminate much of the incentive for capital to migrate from rich to poor countries. Thus the international flows of capital are explained. His major contribution here however was to highlight the role of human capital as a separate input. All labor is not the same, and therefore “unit of labor” should be replaced with “unit of *effective* labor”. According to Lucas, externalities accrue to the economy as a whole from the accumulation of human capital undertaken by individual workers. Lucas then proceeds to treat the externality created by human capital as an input in the production function (Lucas 1988, 1990). The internalities here would be the increase in the marginal product, and therefore the wage, of the worker acquiring knowledge or skill. That would show up as a labor-enhancing force operating through its impact on the marginal productivity of labor.

This can be demonstrated using a Romer/Lucas type production function (Lucas (1988, p.18) equation (11)):

(2.1) $Y_t = K_t^{\alpha} \; (H_{a\,t})^{\beta} \; (A_t (H_t).\; L_t)^{1-\alpha-\beta}$

$A_t \, L_t$ is an effective unit of labor which the worker enhances by deliberately accumulating H or human capital in the form of individual education or skills. $H_a$ is a social index of the average or general level of education or skills. And even though Lucas demonstrates that H and $H_a$ are related, he adds that $H_a$ generates the externality because: "all benefit from it, [but] no individual human capital accumulation decision can have an appreciable effect on $H_a$, so no one will take it into account in deciding how to allocate his time" (Lucas 1988, p. 18). So the technology shifter A here is presumed to be a positive function of H. But that impacts output only by raising the marginal product of the last unit of labor in use. Beyond that there are the externalities accruing to society or the economy as a whole from the individual pursuit of human capital accumulation. Thus the exponent β in $H_{a\,t}^{\beta}$ , is interpreted by Lucas as the percentage increase in productivity or income as a result of a one-percent increase in the average quality of coworkers (Lucas 1990, p.94). Mind you the counter- intuitive point here is that what we are calling an externality, i.e, $H_{at}^{\beta}$, is an input, and what we are calling an internality (as an antonym of externality), plays the role of technology shifter. But that should not be very confusing if we kept in perspective that the above is a production function for the economy or society as a whole, not of an individual firm or worker. Whatever influences the productivity of the average worker gets subsumed under the title of "total factor productivity", or the technology shifter A, otherwise it's an input.

*A Neoclassical Counter-Offensive:*

Before Lucas and Romer explicitly incorporated 'human capital' into models of economic growth, others discussed the concept. Lucas in his article 'On the Mechanics of Economic Development' (1988, p.17) attributes that pioneering honor to Schultz (1963) and Becker (1964). Consequently, Romer and Lucas formally incorporated the already existent concept of human capital into the models explaining economic growth.

Similarly Mankiw, Romer, and Weil (1990), (henceforth MRW), suggested that incorporating human capital as another input into the framework of the Solow model would strengthen that model. This was not presented as a retreat from the standard neoclassical approach towards economic growth, but as an attempt to refine it with more accurate and sophisticated measures of inputs. In fact it was an attempt to absorb the main thrust of "endogenous growth" theories, and turn the tables on them.

Thus, MRW find that "an augmented Solow model that includes the accumulation of human as well as physical capital provides an excellent description of the cross-country data. The model explains about 80 percent of the international variation in income per capita, and the estimated influences of physical-capital accumulation, human-capital accumulation, and population growth confirm the model's predictions"(MRW 1990).

Before that Barro (1989) coined the concept of "conditional convergence". This established that the Solow model did not imply that countries would necessarily reach the same exact steady state level of income, but that given each country's respective saving and population growth rates, each country would arrive at its own steady state level of income.

Then the idea of conditional convergence found its more formal treatment and empirical support in further research by Barro and Sala-i-Martin (1992). The model presented by Mankiw, Romer, and Weil (MRW) represented a sharpening of the Solow model by incorporating the concept of "conditional convergence" into it. Countries converged to the same steady state only when they had similar determinants of the steady state.

In a study addressing convergence among 48 states of the United States, Barro and Sala-i-Martin find that convergence exists, in that poor states do grow faster than rich ones. But extending the results to 98 countries for the years 1960-85 does not vindicate the Solow model, unless some measures of human capital and government intervention in the economy are added. One unsettling aspect about that model though was that it required very high magnitudes of the output elasticity with respect to physical capital $\alpha$, assuming for example a production function similar to the previous equation

(2.1) $Y_t = K_t^{\alpha} H_{at}^{\beta} (A_t (H_t) L_t)^{1-\alpha-\beta}$.

Thus to establish convergence, values of $\alpha$ equal to about .8 need to be assumed. Empirically this is simply unsubstantiated: the estimated share of capital in total output is much lower than that. But theoretically, a high output elasticity with respect to capital implied that diminishing returns set in very slowly, which in turn implies slow convergence (Barro & Sala-i-Martin 1990).

So for MRW, the principal problem with the Solow model with its two explanatory variables ( i.e., the saving and population growth rates) was not that it did not fit the data very well. On the contrary, "more than half of the cross-country variation in income per capita can be explained by these two variables alone"(MRW 1990, p.1). The principal problem was that even though the Solow model "correctly predicts the direction of the effects of saving and population growth, it does not correctly predict the magnitudes" (Ibid). What this amounts to is estimated coefficients for these two variables that are deemed too high in absolute value. As a result the estimate of $\alpha$, the output elasticity with respect to capital, is viewed as too high. For three samples of countries, the largest of which includes 98 countries, and the smallest of which includes the 22 OECD with populations greater than one million, the $\alpha$s are respectively .6, .59, and .36. And even though an $\alpha$=.36 for the OECD sample might seem like a tremendous improvement, the overall econometric validity of that regression is in great doubt, because the coefficients of the saving and population growth rates are insignificant and the explanatory power of the regression is quite low.

To elaborate, in terms of the Solow model, starting from a production function such as $Y_t = K_t^{\alpha} (A_t L_t)^{1-\alpha}$ the equation to be estimated is:

(2.2) $\ln [Y_t / L_t] = \ln A_0 + gt + (\alpha/1-\alpha) [\ln S_t - (\alpha/1-\alpha) \ln (n_t+g+\delta)]$

where $Y_t / L_t$ is real output per worker, $S_t$ is the saving rate, measured as investment as a proportion of income, and $n_t$ is the exogenous population growth rate at time t. A is the initial level of technology. g is the exogenous growth rate of technology assumed to be equal to .02, and $\delta$, the coefficient of depreciation, is equal to .03. $g + \delta = .05$ are assumed to be the same across countries. $\ln A_0$ is the constant term. gt vanishes because MRW estimated this equation for one time period calculating averages for all variables between 1960-85, and thus g becomes part of the intercept which becomes now $\ln A_0 = a + \varepsilon$, where $\varepsilon$ is a country-specific shock or shift term.

Going from the Solow production function above to the regression MRW estimate is a simple process (MRW 1990, pp. 4-5). Diminishing returns to capital in the production function above imply that $0 < \alpha < 1$.

As (2.2) shows, the coefficients of the saving and population growth rate variables are equal in magnitude and opposite in sign; therefore MRW estimate the following restricted equation, after dropping the subscripts t on the independent variables from this point on for convenience:

(2.3) $\ln [Y_t / L_t] = a + (\alpha/1-\alpha) [\ln S - \ln (n+g+\delta)] + \varepsilon,$

as well as the unrestricted specification (2.2).

In the Solow model, as in equation (2.3) above, even if the results are good in terms of explanatory power, t-values, and what have you, the estimated coefficient $(\alpha/1-\alpha)$ may be too large. Then $\alpha$ ends up being too large in terms of the actual share of capital in income, which MRW set at about 1/3.

Even though it is not directly relevant to the main question of this dissertation on explaining cross-country differences in the levels of income, an extension of this problem is that the rate at which convergence to the steady state of income occurs is slow. That rate of convergence is equal to the operator $\lambda$ in the partial adjustment model :

(2.4) $d \ln (y_t)/d t = \lambda [ \ln (y^*) - \ln (y_t) ]$,

where $y^*$ is income in the steady state, and $y_t$ is actual income, and where the hypothesized determinants of the steady state are then substituted back into $\ln (y^*)$.

Since in the Solow growth model $\lambda = (n+g+\delta)(1 - \alpha)$, MRW conclude that if $\alpha$ is higher than it should be, say .8 or .6 instead of .33, $\lambda$ would be smaller than it should be, and convergence to the steady state is implausibly slow.

MRW sought a solution to the "curse of the of the high $\alpha$", not by bowing before the onslaught of endogenous growth theorists who took a high $\alpha$ to indicate that the assumption of diminishing returns is unwarranted, but by adapting the innovation of endogenous growth theorists, i.e., viewing human capital as an input, into the conventional Solow production function while maintaining the Ricardian edifice of diminishing returns to all capital tangible and intangible alike. Capital is now differentiated into tangible and intangible. Their new production function is now $Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta}$ with H as human capital at time t, and the rest of the variables as before. Still assuming constant returns to scale and diminishing returns in all capital, i.e., $\alpha+\beta<1$, MRW proceed to derive (1990, pp.11-13):

$$(2.5) \ln [Y_t / L_t] = \ln A_0 + gt + (\alpha/1-\alpha-\beta) \ln S_K + (\beta/1-\alpha-\beta) \ln S_H$$
$$(\alpha+\beta/1-\alpha-\beta) \ln (n+g+\delta),$$

where $S_K$ and $S_H$ are the shares of income going to building physical and human capital respectively, and will be explained further below.

Again, equation (2.5) can be rewritten in restricted form as:

$$(2.6)\ \ln [Y_t / L_t] = \ln A_0 + gt + (\alpha/1-\alpha-\beta)\,[\ln S_K - \ln (n+g+\delta)] + (\beta/1-\alpha-\beta)\,[\ln S_H - \ln (n+g+\delta)]$$

Recovering the estimates of $\alpha$ and $\beta$ after estimating the regression above for the same three samples as before, MRW obtain an $\alpha$ equal to .31, .29, and .14, and a $\beta$ equal to .28, .3, and .37 for each of the three samples respectively. Now with estimates of $\alpha$ that are much more realistic, MRW declared victory and went on to tackle the question of convergence after taking human capital into consideration.

With the inclusion of human capital, the convergence or partial adjustment operator $\lambda$ is no longer equal to $(n+g+\delta)(1 - \alpha)$ as before but to $(n+g+\delta)(1 - \alpha - \beta)$. MRW find that convergence is faster after the inclusion of human capital as gleaned from a higher estimate of $\lambda$.

*Back to Basics: No Need to Augment Solow's Model*

In a subsequent paper, Nazrul Islam (1995) argues that MRW did not need to include human capital in Solow's model to have it fit the data. Solow's model might fit the data well with relatively low values of $\alpha$ and high values of convergence between countries, if intrinsic differences between countries were taken into account. Islam called this "capturing the country effects". He argued that what has handicapped empirical research on economic growth so far has been the implicit "assumption of identical aggregate production functions for all countries. Although it has been correctly felt that the production function may actually differ across countries, efforts at allowing for such differences have been limited by the fact that most of these studies have been conducted in the framework of single cross-country regressions" (p.1127).

Thus Nazrul Islam (1995) suggests that using the econometric technique of Least Squares with Dummy Variables (LSDV) on panel data , enables one to estimate a distinct intercept term that accounts for the different technology, resource endowments, institutions, and stock of human capital, for each country using dummy variables.

Contrary to MRW, Nazrul Islam insisted that the error term in the estimated regressions (2.2) and (2.3) is not independent of the explanatory variables in Solow's model. That is one can not assume the error term in $\ln A_0 = a + \varepsilon$ as independent of the saving and the population growth rates. MRW had to make that assumption of independence because they applied OLS to a cross-section. However, that assumption may be unwarranted because unobservable country effects implicit in $A_0$ may affect the saving and the population growth rates. Disregarding this by assuming a common constant term relegates the variation in the individual country effects to the error term, and thus injects systematic correlation between the independent variables and the error term, which is a violation of one of the basic assumptions of OLS.

One way to deal with this problem is to estimate Solow's model using LSDV on panel data. LSDV assumes a different intercept for each country. "Moving from a single cross-section spanning (an average of) the entire period to cross sections for the several shorter periods that constitute it...The panel data setup allows us, after controlling for ..the unobservable country effects .. to integrate this process of convergence occurring over several consecutive time intervals.. for the relationship among the measurable and included variables to emerge" (Islam 1995, p.1137).

Using the same samples and time period MRW used, Islam then proceeds to test Solow's model using averaged data in a single cross-section regression. He finds, as they do, very low rates of convergence and very high values of output elasticity with respect to capital $\alpha$. Then he obtains similarly bad results from applying OLS to (non-averaged) pooled data for the whole period. So far this reproduces the work of MRW. But from this point on, Islam uses the Minimum Distance estimator (MD), then LSDV, on the pooled data to estimate the original Solow model. He finds estimates of a faster rate of convergence, and lower shares of capital in income, equal to $\alpha$= .43, .45, and .2 from the largest to the OECD sample respectively, without including any measure of education or human capital in the regressions. Islam's estimates of $\alpha$ however, are larger than the $\alpha$= .31, .29, and .14 that MRW obtained by including human capital in the production function. The latter estimates are arguably much closer to the share of capital in total income. On the other hand, Islam's implied rates of convergence to the steady state are an improvement because they are much faster than MRW's.

Moreover, an interesting aspect of Islam's results is that unobservable country effects, $A_0$ , are an important determinant of cross-country growth dynamics. Islam concludes that " the $A_0$ term is an important source of parametric difference in the aggregate production function across counties. The process of convergence is thwarted to a great extent by persistent differences in technology level and institutions"(p. 1149).

The importance of that conclusion is twofold:

1 - In terms of policy activism, Islam suggests that if countries with similar rates of saving and population growth have no hope of converging to the same steady state level of income as long as differences in $A_0$ persist, then this new finding indicates the need for more rather than less policy targeting the components that make up $A_0$ (p.1162). Islam finds this result theoretically interesting because it reconciles neoclassical growth empirics with development economics, especially as the latter traditionally tended to emphasize the elements that go into $A_0$ , whereas the former emphasized saving and fertility.

2 - In terms of the debate that raged between neoclassical and endogenous growth theorists, this new result of significant country effects may illustrate the essence of the whole discussion. Robert Lucas (1988) pointed out that "both Solow and Denison were attempting to account for the main features of U.S. economic growth, not to provide a theory of economic development, and their work was directed at a very different set of observations from cross-country comparisons...The most useful summary is provided in Denison's 1961 monograph, *The Sources of Economic Growth in the United States.* " (p. 7).

Barro (1990) demonstrated that the conventional Solow model does work for a sample of 48 U.S. states between 1840 and 1963, but not in explaining cross-country variations in economic growth without including additional variables like education and government spending.

Thus, if what Lucas said above were true, Solow's model failed to explain the determinants of economic growth in cross-country samples because it was strictly the outgrowth of U.S. economic history. What Nazrul Islam contributed then was an extension of Solow to a cross-country context simply by demonstrating the importance of taking these countries general circumstances implicit in $A_0$ (technology, resources, climate, policies, and institutions) into account.

Furthermore, in commenting on the new findings Islam says that his study "highlights the role of the $A_0$ term as a determinant of the steady state of income. It thus brings to the fore the fact that, even with similar rates of saving and population growth, a country can directly improve its long-run economic position by bringing about improvements in the components of $A_0$ . Also, improvements in $A_0$ can have salutary effects on s and n (the saving and population growth rates respectively) leading to a further indirect increase in the steady state level of income" (Islam 1995, p.1162).

*The Irrelevance of Human Capital to Solow?*

Nevertheless, Islam relentlessly marches on to eradicate the necessity of augmenting Solow's model with human capital as MRW did by redoing all his regressions with a proxy for human capital included. Then he finds just like MRW do that for the averaged single cross-section data, the output elasticity with respect to capital $\alpha$ is slightly lower, and the rate of convergence $\lambda$ is higher, but the output elasticity with respect to human capital $\beta$ is found significant only for one of his samples. Furthermore, his results even for this regression are not as good as MRW, because his estimates of $\alpha$ are .68, .69, and .54 respectively. Of course he was obtaining his estimates with models of disequilibrium (no steady state) by including a lagged value of the dependent variable, while MRW obtained their initial estimates of $\alpha$ under the assumption of a steady state. So the models themselves might not be directly comparable, even though the $\alpha$s themselves should be.

Including a proxy for human capital in the pooled (non-averaged) data using OLS, causes the results to deteriorate as estimates of $\alpha$ increase to .8, .78, and .6 respectively, as convergence rates decrease, and as the elasticity of output with respect to human capital turns out to be statistically insignificant in all of the three different samples.

Including a proxy for human capital in the fixed effects model yields results that are close to those obtained without the inclusion of a proxy for human capital. Estimates of $\alpha$ are .52, .49, and .2 respectively, which are close but slightly higher than the LSDV estimates without human capital. The implied rates of convergence are close but slightly lower compared to the case of LSDV without human capital. But the output elasticity with respect to human capital $\beta$, consistently has a negative correlation with per capita income. This negative sign suggests that human capital might be inversely related to the standard of living which seems to disprove the original intent of including human capital in the model.

Islam adds that " whenever researchers have attempted to incorporate the temporal dimension of human capital variables in growth regressions, outcomes of either statistical insignificance or negative sign have surfaced [For one such example see De Gregorio (1991)]" (p.1153). He argues that this may be due to unsuitable measures or badly chosen proxies for human capital. Both he and MRW use enrollment rates in high school as a proportion of eligible population as their proxy for human capital on the pretext that this might measure the opportunity cost to society of investing in education. MRW (1990, p. 15) include a discussion devoted to the inappropriateness of that proxy as a measure of investment in education, because some of the expenditure on education could actually be a form of consumption for example. Islam however adds that the reason for the negative sign might be that it measures quantity not quality, and since in reality human capital has not increased that much, "this results in a negative *temporal* relationship between the human capital variable used and economic growth within countries" (1995, p.1153).

On the other hand, a related paper by Benhabib and Spiegel (1994) opens up a multitude of venues by which human capital could affect economic growth. From that base Islam shows that two measures of human capital, enrollment rates and average years of education, are both very highly positively correlated with the estimated values of $A_0$ from his model. Therefore he concludes that instead of its direct inclusion as a separate input, perhaps human capital practices its impact through $A_0$ (p.1161-2). If $A_0$ is viewed as total factor productivity, then education could simply be shifting the technology shifter itself up.

This idea of considering human capital as a shifter of the technology function rather than a separate input as MRW imply did not begin with Nazrul Islam either.

Analyzing the role of human capital in economic growth at length, Benhabib and Spiegel (1994) [henceforth BS] estimated a log-difference of a variation of the MRW production function that didn't give any role to human capital in enhancing total factor productivity, but which entered only as an input as in the following: $Y_t = A_t K_t^{\alpha} H_t^{\beta} L_t^{\eta} \varepsilon_t$, Then using data for 78 countries for the years 1965 and 1985, BS estimated the following regression using OLS (with White's heteroscedasticity-consistent covariance estimation method) :

$$(2.7) \quad (\ln Y_T - \ln Y_0) = (\ln A_T - \ln A_0) + \alpha (\ln K_T - \ln K_0) + \beta (\ln H_T - \ln H_0) + \eta(\ln L_T - \ln L_0) + (\ln \varepsilon_T - \ln \varepsilon_0)$$

Benhabib and Spiegel (1994) found that their measure for human capital is not a significant determinant of economic growth as a separate input, and in fact that its coefficient has a negative sign when significant.

On the other hand, when modeled as a propeller of total factor productivity, human capital was significant. In that context human capital was viewed as important for two complementary reasons: 1) nations develop due to their ability to innovate, and/or 2) nations catch-up with more advanced nations due to their ability to emulate. Both innovation and emulation are dependent on the available stock of human capital.

Take one of their modified functions, for example, based on the defining assumption that human capital was purely a technology shifter as in the production function $Y_t = [A_t(H_t)]\, K_t^{\alpha} L_t^{\eta}\, \varepsilon_t$. Then log differencing as before BS generated :

$$(2.8) \quad (\ln Y_T - \ln Y_0) = c + (g - m)H_i + m\, H_i\, (Y_{max}/ Y_i) + \alpha\, (\ln K_T - \ln K_0) + \eta(\ln L_T - \ln L_0) + (\ln \varepsilon_T - \ln \varepsilon_0)$$

where c is the exogenous technological progress coefficient, g is the endogenous innovation parameter, and m is the catch-up with the more advanced country parameter, and where technological change $(\ln A_T - \ln A_0)$ is supposed to be a dependent on human capital according to the following specification:

$$(2.9) \quad (\ln A_T - \ln A_0) = c + (g - m)H_i + m\, H_i\, (Y_{max}/ Y_i)$$

Now compare the function Benhabib and Spiegel (1994) originally estimated and that which was supposed to measure the effect of human capital as a separate input, i.e., compare regressions (2.7) and (2.8):

$$(2.7) \quad (\ln Y_T - \ln Y_0) = (\ln A_T - \ln A_0) + \alpha\, (\ln K_T - \ln K_0) + \beta\, (\ln H_T - \ln H_0) + \eta(\ln L_T - \ln L_0) + (\ln \varepsilon_T - \ln \varepsilon_0)$$

$$(2.8) \quad (\ln Y_T - \ln Y_0) = c + (g - m)H_i + m\, H_i\, (Y_{max}/ Y_i) + \alpha\, (\ln K_T - \ln K_0) + \eta(\ln L_T - \ln L_0) + (\ln \varepsilon_T - \ln \varepsilon_0)$$

What BS effectively did was get statistically insignificant estimates for $\beta$ in regression (2.7) and therefore conclude that human capital is not an input. They also get significant estimates of m (in $m\, H_i\, (Y_{max}/ Y_i)$) in regression (2.8) and conclude that the catch-up effect may be the channel through which human capital affects total productivity growth. The problem here is not their identification of catch-up or innovation effects, but their conclusion that the presence of these effects indicates that human capital is not an input. BS find a positive and significant coefficient for g-m (in (g - m)H) in their sub-sample of rich countries only, and thus conclude that implies innovation effects for human capital in those countries. But by the same token, could we not have claimed that human capital becomes a social input as an individual externality only beyond a certain high level when enough of it is accumulated? The point is that human capital may not be an input, but we can not conclude that based on the results of regression (2.8) alone, and thus the question of whether human capital is an input or not remains an open one.

Three propositions on the relationship between human capital and economic growth are thus deduced (Benhabib & Spiegel 1994):

1 - When differences in human capital stocks between countries primarily affect the technological innovation function, growth rates may differ across countries for a long period of time.

2 - When a technologically backward country accumulates a higher stock of human capital than a more advanced country, it will catch up with and even overtake the more advanced country in a finite period of time.

3 - "the country with the highest stock of human capital will always emerge as the technological leader nation in finite time and maintain its leadership as long as its human capital advantage is sustained" (p. 145).

These propositions run contrary to the idea propounded by Lucas and MRW that human capital is an input. They also may have provided the impetus for researchers like Nazrul Islam to look in a different direction, for example towards country effects, to explain why the textbook Solow model does not fit the international data. ...We need to keep in mind that as Nazrul Islam puts it: "Benhabib and Spiegel, however, limit their analysis to single cross-section regression with some variables entering in the first differenced form" (p. 1154).

Therefore, we may not be able to disregard their essential result on the different ways human capital may affect technology, but in the catch-up case especially (p. 158), as well as in their fully developed structural specification (p. 161), the human capital variable exerts its econometric influence directly on per capita GDP in the function albeit under the disguise of having been substituted into some technology function. The question would then remain open as to whether human capital is a separate input or not because based on that estimate alone, one can not determine if a significant coefficient there implies an input or a shifter.

As for Nazrul Islam, even though his country effects were significant, and his convergence rates are among the most plausible in the growth literature so far, his recovered estimates of $\alpha$ were a little too high compared to MRW and to the actual share of capital in income; an estimated $\alpha$ equal to .43 for the large sample and of .45 for the middle sample is not an improvement on the results of MRW, but rather a deterioration.

This means that it might be too early to dismiss human capital or other variables as irrelevant to the extension of the Solow model, even though Islam has obviously made an effective case for country effects. It stands to reason that human capital may affect total factor productivity among other variables, but that leaves open the possibility that these variables also may be contributing something to economic growth in the way of positive externalities, or social inputs in an aggregate production function as alluded to by Romer and Lucas above. Therefore, different variations on MRW and Islam's models need to experimented with to further explore and gain more insight into this matter.

# CHAPTER III

## INTRODUCING URBANIZATION

Rather than introducing urbanization abruptly into the conventional models of economic growth, below I present an overview of how the impact of some other variables on economic growth was tested by economists in the framework of the growth models of Solow or Barro . By parallel analogies, we can better see where urbanization fits in the growth context.

*Testing Other Variables*:

Using the frameworks previously developed to analyze economic growth, many economists sought to understand the impact of other nonstandard variables on the process of economic growth.

For example Helliwell (1992) introduces measures of democracy and human rights directly into the equation of MRW, with human capital included, to find that 1) countries with higher income have more democracy, 2) democracy seems to have a weak negative direct impact on economic growth, and 3) democracy seems to have a strong positive impact on investment and schooling both of which have a strong positive influence on economic growth. These results were generated with the benefit of the model built by MRW, but also with equations showing the effects of income on measures of democracy and the effects of measures of democracy on education and investment, which are supposedly inputs in the aggregate production function used by MRW.

Sachs and Warner (1995) test the relationship between natural resource endowments and economic growth in the context of a number of well-known economic growth models, including MRW's and Barro's. Through a system of regressions built to study the interrelationships between different facets of the economy, they show that countries that had a high ratio of natural resource exports to GDP, where natural resources are defined as agriculture, minerals, and fuels, had a lower, and even negative GDP per capita growth between 1970 and 1989.

An interesting explanation of this empirical finding is the so-called "Dutch" disease. In an economy made up of three sectors, a manufacturing, primary goods, and a non-traded goods sector, the interrelationships between the sectors are such that more demand in the primary goods sector implies more demand for the output of the non-traded goods sector. But as the manufacturing sector gets squeezed out, economic growth diminishes because the manufacturing sector is assumed to be shrouded in externalities because of its more extensive division of labor and more numerous forward and backward linkages. Moreover, this effect might trigger a protectionist response which further causes GDP per capita to decrease.

With findings that they deem empirical support for the theory above, Sachs and Warner (1995) conclude that "natural resource intensity and openness represent additional explanations for cross-country growth that have not been considered by other studies" (p.15). They also find that "there's evidence for conditional convergence, as suggested by neoclassical models of economic growth" (p.22).

Furthermore, using his model of economic growth, which is not all that dissimilar from MRW's in the variables included with the exception of political ones which MRW disregard, Barro (1996) investigated the effects of inflation on growth and investment and found it to be significantly negative albeit not very large in magnitude! He also pointed out that his empirical results are heavily influenced by the experience of a relatively small group of very high inflation/low growth countries. In obtaining these results, Barro included other variables as controls for government spending, democracy, and market openness and competitiveness in addition to myriad conventional measures of fertility, investment, and education.

*Excluding Urbanization*:

At this point one may legitimately wonder where urbanization fits in this context, and how it affects economic growth. Generally speaking one only finds few studies on the effect of urbanization on economic growth. In fact, a recent survey by Barro and Sala-I-Martin (1995) on the subject of economic growth does not directly acknowledge any measure of urbanization as a growth determinant in any of the models surveyed. Yet on a purely heuristic level, if one should not ignore the role of economies of scale or of human capital in raising the standard of living, one should not ignore the contribution of agglomeration economies in generating economic growth.

This lament on the nonexistence of empirical studies relating urbanization as an independent variable in economic growth is not to say that the effect of urbanization on economic growth has gone completely unnoticed. Robert Lucas (1988) in his 'On the Mechanics of Economics Development', devoted the last section of that well-known paper to call for a discussion on the relationship between cities and economic growth. In that section he explicitly embraces the theories of Jane Jacobs as *he draws parallels between the role of cities in economic growth and the role that he postulates for the externalities of human capital in economic growth* (p.38). He wonders: "The theory of production contains nothing to hold a city together. A city is simply a collection of factors of production - capital, people, and land - and land is far cheaper outside cities than inside. Why don't capital and people move outside, combining themselves with cheaper land and thereby increase profits? Of course, people like to live near shopping and shops need to be located near their customers, but circular considerations of this kind explain only shopping centers, not cities. Cities are centered on wholesale trade and primary producers, and a theory that accounts for their existence has to explain why these producers are apparently choosing high rather than low cost modes of operation" (p.38).

Hence Lucas recognizes the role of agglomeration economies in the establishment of cities. But more than that he goes on to impart these economies with a mystical 'force' that gives rise not only to cities but also to economic development itself: "It seems to me that the 'force' we need to postulate to account for the central role of cities in economic life is of exactly the same character as the 'external human capital' I have postulated as a force to account for certain features of aggregative development" (p.38-9).

Initial empirical support for a possible role in economic growth of at least some forms of urban concentration comes from Shatter and Moomaw (1992). They find that "primacy has a significant negative effect on economic growth, and metropolitan concentration has a significant positive effect on economic growth. The urban percentage is insignificant" (p.13), where urban percentage is the percentage of total population living in cities. Primacy is defined as the population of the largest city as a proportion of the total urban population, and metropolitan concentration is the population of cities above a certain cutoff point like 250 thousand typically, and 100 thousand in Shatter's case, as a proportion of the total urban population.

Thus, including those three measures of urban concentration in Barro's model of economic growth, Moomaw and Shatter find that two cross-section regressions for seventy-one countries, where the dependent variable is the change in per capita income between 1960-85 and 1970-85 respectively, yield the following preliminary results:

1) "Urbanization patterns do have an impact on economic growth",
2) "Large cities may inhibit economic growth", and
3) "A concentration of economic activity in metropolitan areas appears to enhance economic growth" (p.13)

*Other Sources of Inspiration:*

Additionally this inquiry has been motivated by papers by Rauch (1993) and Glaeser et al. (1992) which tackle productivity gains from the geographic concentration of human capital, and growth in cities, respectively. These writers emphasize the roles of knowledge spillovers and technological externalities in the growth of wages and employment in cities, and more specifically Metropolitan Statistical Areas (MSAs) in the United States. These externalities arise either from the accumulation of education and experience in the same location, and /or the competition and interaction of firms and employees from diverse industries in the same urban place.

Hence it is through the concentration of human interaction and communication in the spatial confines of the metropolitan locus that these externalities take shape and gain effect. They cause increases in productivity, and therefore the standard of living, above and beyond the direct effects expected from the accumulation of education and experience alone. For any given country as a whole, this locational effect should be reflected in productivity gains above and beyond those obtained from amassing inputs, including human capital.

Moreover, Rauch (1993) demonstrates that wages (and rents) grow faster where there are higher geographic concentrations of human capital. Whether one upholds the endogenous version about how human capital should enter the production function, or that of MRW, this locational effect might be an *additional* reason why the inclusion of human capital in Solow's model makes it fit the data better. Perhaps human capital is contributing something extra in the way of an externality as some suggest, as well as proxying for the effects of knowledge spillovers arising from urban concentration.

Either way the microeconomic basis of these knowledge spillovers is presented by Rauch (1993) from a model of formal and informal interactions by Jovanovic and Rob (1989) in which:

> ...individuals augment their knowledge through pairwise meetings at which they exchange ideas. In each time period each individual seeking to augment his knowledge meets an agent chosen randomly from a distribution of agents/ideas. (Rauch 1993, p.381).

Then Rauch adds:

> ...intuitively it seems clear that the higher the average level of human capital (knowledge) of the agents, the more the "luck" the agents will have with their meetings and the more rapid will be the diffusion and growth of knowledge. If this knowledge concerns technological improvements, we have a microeconomic foundation not only for the external effects of human capital on total factor productivity, but also for making those effects dependent on the average level of human capital (Ibid).

But mind you, Rauch is referring to external effects that are dependent on *being in a specific location*, as can be seen in the following:

> Given the existence of human capital externalities, economically identical workers will tend to earn higher wages in human capital rich, rather than in human capital poor, countries. This result is consistent with the large net realized migration from the latter to the former countries and unsatisfied demand for further migration (ibid).

Using the 1980 Census of Population in the United States, the regressions Rauch estimates are log-linear wage and rent hedonic equations that use observations on 69,910 individuals and 44,758 households residing in 237 SMSAs. After accounting for all the individual characteristics that may enter into determining a person's earning patterns, the average levels of education and experience in the SMSA where s/he resides are added to the list of independent variables. Then the same is done to estimate the rent function any given residential structure might command.

The results show unequivocally that an increase in the average levels of education especially, and to a lesser degree the average level of experience in a given SMSA, cause a substantial increase in the wages and rents in that SMSA. In fact, a one year increase in the average education of the people in your SMSA, cause your income on the average to increase by 2.8% after accounting for the regional differences with dummies. Without regional dummies, your income would increase by 5.1% if the average years of education in your SMSA increased by one year. Compare that to an increase of 4.8% in your income if your own education increased by one year, with or without regional dummies.

This effect of shifting the earning function up as a result of intertwining education and urban concentration will be referred to from here on as the Rauch effect.

As for rent gradients, the increase is much higher. An increase of one year in the average years of education of your fellow metropolitanites, increases your rent somewhere between 13 and 20% depending on whether regional dummies are included or not, in which case the observed differences in rent become smaller (13%).

Furthermore, Glaeser et al. (1992) find empirical evidence for knowledge spillovers in cities. They also find that employment and wage growth occurred more intensively in cities where many industries are represented. The implication here is that these spillovers occur between rather than within industries. That is a finding which lends grace and support to the theories of Jane Jacobs as expressed in her famous books The Economy of Cities (1969) and Cities and the Wealth of Nations: Principles of Economic Life (1984), over the theories of Marshall (1890), Arrow(1962), and Romer (1986) who tended to think that knowledge spillovers occur between firms in the same industry.

Using industries in 170 U.S. cities between 1956-87, Glaeser et al. (1992) indicate *that these are dynamic externalities as opposed to static externalities*, resulting essentially from urban concentration rather than localization. And even though Glaeser et al discuss more traditional determinants of economic growth in cities in a different paper (1995), where they find city growth in terms of both income and population positively related to the level of initial schooling too (i.e. direct effect of human capital not knowledge spillovers), the 1992 paper stands out for its original contribution on the role of locational externalities, specifically knowledge spillovers, in the growth of cities.

To appreciate the depth of what Glaeser et al (1992) did, and their relevance to the issue of economic growth in general, we should first distinguish between *dynamic and static agglomeration economies* . Recall that agglomeration economies are obviously either localization or urbanization economies. These economies explain why cities of different sizes exist, where they exist, and how big they get. But that relates to static textbook externalities only, which purport to explain locational patterns and city size and hierarchy.

An example of static localization economies is the saving accruing from locating next to inputs to save on transportation cost, an idea first espoused by Marshall. The past concentration of the steel industry in Pennsylvania, and of the auto industry in Detroit, indicates the presence of localization economies.

Static urbanization economies on the other hand are savings that arise when several different firms from different industries locate next to each other in the same urban place to take advantage of common police and fire protection, business laws, tariff exemptions, cheaper utilities, benefits from allowing consumers to do comparison shopping, etc.. Evidence of urbanization economies can be detected from the congregation of all kinds of businesses in the crowded central business districts of many third world cities, and perhaps from the huge malls of the United States.

In arguing the benefits of urbanization over localization economies or vice versa, writers like Henderson (1986), Nakamura (1985), and Moomaw (1988), have tended to find to different degrees that evidence of localization economies overwhelms evidence of urbanization economies. This is consistent with Glaeser et al (1992) too. As Moomaw (1988) puts it: "Localization and urbanization economies are consistent with and perhaps provide the basis for the observed locational patterns of various industries"(p.151). Glaeser points out also that "static localization [and urbanization] externalities can thus easily account for city [and industry] specialization, *but not for growth*"(p.1129).

The key then to understanding the difference between static and dynamic externalities is to realize that static relates to savings or benefits reaped once, as when the average cost curve shifts down, or when the production function shifts up, and stays there unless you change what caused it to shift in the first place like move back from California or New York to West Virginia if you're a firm specializing in fashion design or movie-making, or vice versa if you produce coal in Appalachia. For example, "Henderson (1986) in particular presents empirical evidence indicating that output per labor-hour is higher in firms that have other firms from the same industry located nearby" (Glaeser et al. 1992, 1129).

Dynamic externalities such as knowledge spillovers on the other hand are sources of *permanent* city growth. They explain why income grows, and these are the ones that are more likely to take place between, rather than within industries, and thus they are in that sense dynamic urbanization extenalities. "The most important knowledge transfers come from outside the core industry. As a result, variety and diversity of geographically proximate industries promote innovation and growth. One example is the brassiere industry, which grew out of dressmakers' innovations rather than the lingerie industry" (Glaeser et al. 1992, p. 1128). Other examples include the financial services industry which grew out of the activities of New York grain and cotton merchants, and equipment leasing, which was invented by a San Francisco food processor not by the banking industry (Ibid, p. 1132).

Thus after using city-industry as a dependent variable, the empirical findings of the study by Glaeser et al.(1992) reinforce the conclusions above. A city-industry of course would be something like New York business services, New York printing, or Albuquerque business services as measured by the number of those employed in that industry in that city, or the change in that. Thus, Glaeser et al (1992) find that:

1 - "In a cross-section of city-industries, we find that, as measured by employment, industries grow slower in cities in which they are more heavily represented"

2 - "industries grow faster in cities in which firms in those industries are smaller than the national average size of firms in that industry"

3 - "city-industries grow faster when the rest of the city is less specialized" (p.1129).

On the other hand, Glaeser et al (1992) mention that an important objection to their results may be that they were "looking at a period in U.S. history in which traditional manufacturing industries have fared poorly because of import competition and at particular very mature cities. Our results may then not be applicable for more dynamic time periods or places" (p.1151). If the above objection holds however, that may mean only that dynamic externalities may be more localization than thought of before. Glaeser et al. (1992) argue that the evidence shows that cities and income grow more or less as a result of knowledge spillovers across industries. Hence the contribution of cities to economic growth.

Glaeser et al. (1992) also find that employment growth in a city- industry helps wage growth in that city-industry, even though the opposite in not true, i.e., higher wages do not help employment growth, which should not come as a complete shocker given the Law of Demand. The results indicate however that growing cities provide more and better jobs and thus a higher standard of living.

Using a simple expansion multiplier and the stimulated demand for the intermediate products of other industries through forward and backward linkages, this growth caused by knowledge spillovers causes the whole economy to grow as well. That is the basic idea behind including measures of urbanization as inputs in the production function, instead of letting them languish in the constant term where they have been for the last few decades.

Other researchers have also confirmed the result of the existence of knowledge spillovers. For example, in a comparative study of American states, Acs, Audretsch, and Feldman (1994) found that successful implemented innovations (as opposed to patented inventions) are more numerous where private industry laboratories are in geographic proximity to university R&D laboratories. Acs et al. (1994) also provide an answer to the puzzling pattern "identifying a vigorous amount of innovative activity emanating from small firms in certain industries". How can small new firms "generate innovative output while undertaking negligible amounts of investment into knowledge-generating inputs such as R&D?" Answer: "Through exploiting knowledge created by expenditures on research in universities and on R&D in large corporations"(p.137).

On the other hand, narrowing the focus down to universities specifically, Beeson (1993) finds, among other things, that "area employment growth rates are positively related to changes in R&D funding, as well as to the number of nationally rated science and engineering programs at local universities"(p.759).

All of the above suggests that developing a framework within which the role of large cities on economic growth could and should be undertaken . This would help us attain a better understanding of the enigma of economic growth. The formal treatment of this model is the task we turn to in the next chapter.

# CHAPTER IV

## The Model: A Derivation

Starting with a Solow-type CRS production function for the whole economy, Mankiw, Romer,and Weil (1990) add human capital H to obtain:

(4.1) $Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta}$, with $\alpha+\beta<1$,

where Y is output, K is capital, L is labor, A is the level of technology, and H is human capital, while the subscript t indicates that all of the above are being measured at a given time t.

In this construction, A and L are assumed to be growing exogenously at the rates g and n respectively according to the following equations:

(4.2) $A_t = A_0 e^{gt}$ and

(4.3) $L_t = L_0 e^{nt}$

As Mankiw, Romer, and Weil (1990) emphasize, the assumption that $\alpha+\beta<1$ is a crucial one because it implies that there are diminishing returns to all capital. "If $\alpha+\beta=1$, then there are constant returns to scale in reproducible factors. In this case, there is no steady state for this model" (p.12). If there's no steady state, there's no convergence. This means that the rich countries can go on getting richer without poor countries ever being ever able to catch up with them. Since the intention is to formulate and test a model with diminishing returns to all capital, we impose the condition above that $\alpha+\beta<1$.

*Two Modifications:*

The model to be developed introduces two modifications to the model of Mankiw, Romer, and Weil (henceforth MRW) above.

These two modifications are:

1) the inclusion of an index of urban concentration into MRW's function to gauge the effects of agglomeration economies in economic growth. The rationale for this is discussed below.
2) partially endogenizing $A_t$, otherwise defined as the level of technology by some, and total factor productivity by others, by making it a function of urbanization and human capital. Making $A_t$ a function of human capital has been explored by Benhabib and Spiegel (1994) and making it explicitly a function of urbanization has been loosely treated in Jane Jacobs (1969) and James Rauch (1993) as explained in the previous chapter.

The first modification transforms MRW's production function into:

(4.4) $$Y_t = K_t^{\alpha} H_t^{\beta} U_t^{\gamma} (A_t L_t)^{1-\alpha-\beta-\gamma}$$

where U is urban capital, measured by an index of urban concentration. Because of the role large cities play in economic growth we should perhaps speak of metropolitan concentration and metropolitan capital, or urban agglomeration and agglomeration capital. In what follows, "urban capital" will refer to urban agglomeration.

The second modification makes it possible to rewrite (4.4) as:

(4.6) $Y_t = K_t^{\alpha} H_t^{\beta} U_t^{\gamma} (A_t (U_t,H_t) L_t)^{1-\alpha-\beta-\gamma}$

To be consistent with the neoclassical assumption of diminishing returns to scale in all capital, we impose the overarching condition that $\alpha+\beta+\gamma<1$ on the new model which incorporates urban capital above.

*Theoretical Justification for Adding U to the Aggregate Production Function:*

This is the age of non-tangible inputs. If capital K may be decomposed into human and physical components by virtue of a distinct contribution to productivity precipitated by investment in non-material means of production such as knowledge, skills, or experience, a case can be also made for the existence of another non-tangible input to be called urban capital $U_t$.

If urban economists are justified in indicating the presence of agglomeration economies, prompted by savings arising from rational location decisions (as separate from economies of scale, prompted by the sheer scale of production), then those agglomeration economies make a unique and independent contribution to output. Arising solely from the interaction of the location decisions of many firms and individuals, the congregation, or lack of, of these economic agents, and the patterns of their congregations is taken here to create a unique input: urban capital.

Location in a metropolitan area for example, albeit expensive, occurs to take advantage of agglomeration economies. The most specialized inputs, which produce output with the lowest per capita demand, locate in the largest possible metropolitan areas, brain surgeons being an example. That allows agglomeration economies to fully materialize. Therefore, a less than optimal location decision would contribute negatively to profit just like a less than optimal allocation of labor, physical capital, or raw materials.

In that sense, location is not a geographical concept but an economic one. The same bridge or highway in the same exact place may have a much higher productivity, and therefore value, on the verge of the twenty-first century say than in Roman times. A higher urban concentration in absolute and relative terms around the facility in modern times may perhaps explain the difference.

"Agglomeration economies may arise because firms in larger cities benefit from the availability of a wide range of business services (such as banking, insurance, real-estate, hotels, maintenance and repair services, printing, transportation, and communication ) and public services (such as highways, mass transit, schools, and fire protection). Thus, large cities are both centers of production and services and nodes of exchange of goods and services. Larger cities also provide larger differentiated markets of labor. Greater division of labor in specialized firms reduces production cost relative to unspecialized firms" (Alwosabi 1996, p.41).

"Moomaw (1988) concludes agglomeration economies induce firms to locate close to each other to minimize production and transportation costs. Manufacturing firms which locate in large cities minimize production cost more than firms in smaller cities, even if input prices are higher in large cities.

Moomaw (1981) finds that the productivity advantages of larger cities are much larger for the non-manufacturing sector than the manufacturing sector" (Ibid).

Urban capital then is not just location in an abstract sense, but the configuration and degree of concentration of the aforementioned business and public services arising from individual location decisions. For example, infrastructure in the "wrong" place, as a result of some government plan or decree, does not yield as much urban capital as infrastructure in the "right" place resulting from the presumably rational location decisions of firms and individuals, even though the cost of constructing such infrastructure might be the same in both cases.

On the level of the economy as a whole, a rising urban concentration imparts worth and creates demand for business and public services. To the extent that those services tend to be more concentrated in larger than in small cities, agglomeration economies arise more in metropolitan areas and thus large metropolitan areas become our proxy for urban capital. As pointed out elsewhere, to qualify as capital, urban concentration has to generate dynamic rather than merely static externalities, or agglomeration economies. Static externalities on the other hand may serve as shifters of the production function. Dynamic externalities cause the urban economy to grow over time, and thus propel the national economy forward.

Empirically, there has not been a lack of evidence on a significant relationship between proxies for urbanization and economic growth (Moomaw and Shatter 1993). This study however takes the further step of explicitly incorporating urbanization or urban concentration as an input, and later as a shifter, in the growth equation. A recent general survey of the growth literature by Barro and Sala-I-Martin (1995), indicates that this contribution is original. What remains though is to work out the MRW model mathematically with U included and then to see how well the new specification fits the data or if it contributes to the relevant questions posed by the growth literature.

*Endogenizing Technology*:

Alternatively urban capital could be viewed not as a separate input but merely as a shifter that affects the economy's production function through its impact on technology. In this case, urban capital plays the role of enhancers of total factor productivity through their effect on the level of technology in a country. Total factor productivity here should not be defined in the narrow sense of production technology only, but in the general sense of a country's institutions and infrastructure.

Thus, the second modification to MRW's production function is a specification of variables that affect the level of technology. MRW assumed that technological progress will change at an exogenous rate g as in equation (4.2) above. This rate was taken as uniform across all countries in the sample.

This specification includes technological progress as an exogenous and uniform rate of change, but it also allows urban and human capital to affect the level of technology at time t.

The level of accumulated human and urban capital in a given country will thus contribute to a higher level of technology, if we assume technological innovation to be a positive externality generated at least partially by 1) a generally higher level of knowledge and skills, and 2) the more intense competition and interaction of firms and employees from diverse industries in the same urban place or locale (Rauch 1993).

Thus the second modification implies that $A_t$ is now a function of human and urban capital accumulation as in:

(4.5) $A_t = A_0 e^{gt} A(H,U)$, where $A(H,U) = H^{c1} U^{c2} e^{c3HU}$ $\rightarrow$

(4.5a) $A_t = A_0 e^{gt} H^{c1} U^{c2} e^{c3HU} \rightarrow \ln A_t = \ln(A_0 e^{gt+c3HU} H_t^{c1} U_t^{c2}) \rightarrow$

(4.5b) $\ln A_t = \ln A_0 + gt + c_1 \ln H_t + c_2 \ln U_t + c_3 H_t U_t$

where the interaction term HU implies that the preponderance of urbanization and human capital generates a higher level of technology than the sum of the parts. For the economy as a whole, this is the Rauch effect.

The formulation above keeps the growth rate of technology g exogenous, but makes the growth rate of technology function shift by a constant fraction of the interactive term HU. As long as human and urban capital are NOT assumed to be functions of time however, the slope of the growth rate of technology function remains exogenous. But the level of technology is now dependent on the infusion of human and urban capital, i.e., education as well as business and public services . In other words, the growth rate is still g, but the growth rate function of technology shifts up or down in proportion to the level of human and urban capital available.

Unlike the first modification which envisages urbanization as capital, the second modification contributes to total factor productivity by shifting the production function itself up or down depending on whether that country has more or less human and urban capital. This is tantamount to changing the intercept but not the slope of the growth function. Both possibilities will be explored theoretically as well as empirically in the context of the model developed here.

For example, take equation (4.7) below, after adding an intercept term to equation (4.6):

(4.7) $Y_t = A_0 K_t^{\alpha} (A_t (H_t,U_t)L_t)^{1-\alpha-\beta}$, where $A_0$ is an intercept term that denotes initial conditions.

Thus, equation (4.4) can be rewritten as

(4.7a) $Y_t = A_0 K_t^{\alpha} (A_t (H_t,U_t))^{1-\alpha-\beta} (L_t)^{1-\alpha-\beta} \Rightarrow Y_t = A_0 K_t^{\alpha} A_t^{1-\alpha-\beta} (L_t)^{1-\alpha-\beta} \Rightarrow$

(4.7b) $Y_t = A_0 .A_t^{1-\alpha-\beta} .K_t^{\alpha} .L_t^{1-\alpha-\beta}$

which simply implies the same old production function with a new higher intercept term, $A_0 .A_t^{1-\alpha-\beta}$, by a proportion equivalent to the output elasticity with respect to labor times the coefficients of the relationship between A and H and U. If we make the new intercept, $A_0 .A_t^{1-\alpha-\beta}$, equal to $A_1$, then $\text{Ln } A_1 = \text{Ln } A_0 + 1-\alpha-\beta \text{ Ln } A_t$. This implies that a change of one percent in whatever affects $A_t$ will affect the intercept by $1-\alpha-\beta$, or the elasticity of output with respect to labor, times the coefficients of the function $A_t (H_t,U_t)$.

Note that this result is robust to any returns to scale. For example, even if we had a production function where $Y_t = A_0 K_t^{\alpha} (A_t (H_t,U_t)L_t)^{\eta}$, where $\alpha+\eta=?$, then we would still have $Y_t = A_0 K_t^{\alpha} (A_t (H_t,U_t))^{\eta}(L_t)^{\eta}$, and a coefficient for the proxy of the variable(s) that affect $A_t$ that is necessarily equal to the output elasticity with respect to labor multiplied by the coefficients of the relationship $A=f(H_t,U_t)$.

*Developing the Model:*

Recall that with the two modifications combined, i.e., with (4.5) substituted back into (4.4), the general specification becomes assuming constant retunrs to scale:

$$(4.6)\ Y_t = K_t^{\alpha} H_t^{\beta} U_t^{\gamma} (A_t (H_t ,U_t)L_t)^{1-\alpha-\beta-\gamma}$$

which is of course the same as equation (4.4) above, except that the formulation in equation (4.6), i.e., $Y_t = K_t^{\alpha} H_t^{\beta} U_t^{\gamma} (A_t (H_t ,U_t)L_t)^{1-\alpha-\beta-\gamma}$ is meant to emphasize the inclusion of human and urban capital in the production function both as possible inputs and as shifters of the technology function $A_t$.

Following Lucas (1988,1990), we assume that anything that enhances the productivity of the average worker affects A and relates to total factor productivity; otherwise it's an input. Thus a worker's decision to move to a metropolitan area or to earn a degree in anticipation of increasing his or her income plays out through its effect on that worker's marginal productivity through A.

Nevertheless, the total effect of these individual decisions is more than the sum of the parts. An increase in the metropolitan percentage of the population or the quality of the people one works with generates externalities reflected in the coefficients $\gamma$ and $\beta$ respectively. Then we can speak in terms of urban and human capital as inputs.

Subsequently equations (4.4) or (4.6) above may help us determine in what way and how much H and U contribute to output if any.

*Definitions*:

Let AL be the effective units of labor,

then $k = K/AL$ : Physical capital per effective unit of labor,

$h = H/AL$ : Human capital per effective unit of labor,

$u = U/AL$ : Urban capital per effective unit of labor,

$y = Y/AL$ : Output per effective unit of labor.

*Rates of Growth:*

MRW, Nazrul Islam (1995), and others assume subsequently that k grows as follows:

(4.8) $k^{\bullet}_t = S_K y_t - (n + g + \delta) k_t$

where $S_K$ is the fraction of output invested in building physical capital, assumed constant.

n is the rate of growth of labor,

g is the rate of growth of technology,

and $\delta$ is depreciation.

Thus the equation above implies that the change of the capital-labor ratio, $k^{\bullet}$, is a function of the difference between the fraction of output that is invested and the growth rates of other inputs (labor and technology) and depreciation.

Similarly MRW assumed h would grow as:

(4.9) $h^{\bullet}_t = S_H\, y_t - (n + g + \delta)\, h_t$

where $S_H$ is the fraction of output invested in building human capital, assumed constant, with the rest of the variables as previously defined.

Along the same lines, we assume that u will grow as follows:

(4.10) $u^{\bullet}_t = S_\mu\, y_t - (n + g + \delta)\, u_t$

where $S_\mu$ is the fraction of income invested in building urban capital or infrastructure, i.e., business and public services, also assumed constant, with the rest of the variables as previously defined .

And following Mankiw, Romer, and Weil, we assume that the same production function applies to all three kinds of capital and to consumption, i.e., we adopt the assumption that one unit of physical capital for example can be transformed costlessly into one unit of urban capital or into one unit of consumption. Furthermore, we assume that all three different kinds of capital depreciate at the same rate. Recognizing that these are constraining assumptions, we adopt them to simplify the analysis.

*The Modified Production Function:*

Equation (4.4) $Y_t = K_t^{\alpha} H_t^{\beta} U_t^{\gamma} (A_t L_t)^{1-\alpha-\beta-\gamma}$, can now be rewritten as

Equation (4.6) $Y_t = K_t^{\alpha} H_t^{\beta} U_t^{\gamma} (A_t(H_t, U_t)\, L_t)^{1-\alpha-\beta-\gamma}$ as pointed out before.

Dividing both sides by AL, and momentarily leaving aside the subscript t merely for convenience➔

$Y/AL = y = (K/AL)^{\alpha} (H/AL)^{\beta} (U/AL)^{\gamma}$ ➔

(4.11) $y_t = k_t^{\alpha}\ h_t^{\beta}\ u_t^{\gamma}$

which states that output per effective unit of labor is a function of physical capital, human capital, and urban capital per unit of effective labor.

*The Steady-State Levels of Physical and Human Capital*:

Following MRW, except for adding urbanization, in the steady state, all of the growth rates of k, h, and u are equal to zero by definition. So,

$k^{\bullet}_t = 0 = S_K\, y_t - (n + g + \delta)\, k_t$ ➔

(4.12) $S_K\, y_t = (n + g + \delta)\, k_t$ ,

$h^{\bullet}_t = 0 = S_H\, y_t - (n + g + \delta)\, h_t$ ➔

(4.13) $S_H\, y_t = (n + g + \delta)\, h_t$ ,

$u^{\bullet}_t = 0 = S_{\mu}\, y_t - (n + g + \delta)\, u_t$ ➔

(4.14) $S_{\mu}\, y_t = (n + g + \delta)\, u_t$ .

Then substituting (4.11) above into $y_t$ in each of equations (4.12), (4.13), and (4.14), we obtain the following terms for $k_t$ , $h_t$ , and $u_t$ :

(4.15) $k_t = [(S_K\ h_t^{\beta}\ u_t^{\gamma})/ (n + g + \delta)]^{1/1-\alpha}$

(4.16) $h_t = [(S_H\ k_t^{\alpha}\ u_t^{\gamma}) / (n + g + \delta)]^{1/1-\beta}$

(4.17) $u_t = [(S_{\mu}\ k_t^{\alpha}\ h_t^{\beta}) / (n + g + \delta)]^{1/1-\gamma}$

Then Substituting (4.16) into (4.15), we obtain:

(4.15a) $k_t^* = [(S_K^{1-\beta} S_H^{\beta} u_t^{\gamma}) / (n + g + \delta)]^{1/1-\alpha-\beta}$

where $k^*$ is the steady-state level of physical capital per unit of effective labor, with the level of urbanization included.

Then substituting $k^*$ from (4.15a) back into (4.16), we obtain:

(4.16a) $h_t^* = [(S_H^{1-\alpha} S_K^{\alpha} u_t^{\gamma}) / (n + g + \delta)]^{1/1-\beta-\alpha}$,

where $h_t^*$ is the steady level of human capital per unit of effective labor, with the level of urbanization included.

*Economic Growth with level of Urbanization Included:*

At this stage we can develop one version of the economic growth equation that can be tested econometrically.

Starting out from equation (4.11) and still following MRW :

$y_t = k_t^{\alpha} \; h_t^{\beta} \; u_t^{\gamma} \rightarrow \quad Y/AL = k_t^{\alpha} \; h_t^{\beta} \; u_t^{\gamma} \rightarrow$

(4.11a) $Y_t/L_t = k_t^{\alpha} \; h_t^{\beta} \; u_t^{\gamma} \; A_t$ .

Substituting the steady-state levels of k and h, i.e., (4.15a) and (4.16a) respectively back into (4.11a), we obtain:

$Y_t/L_t = \{[(S_K^{1-\beta} S_H^{\beta} u_t^{\gamma})/(n+g+\delta)]^{\alpha/1-\alpha-\beta}\}. \{[(S_H^{1-\alpha} S_K^{\alpha} u_t^{\gamma})/(n+g+\delta)]^{\beta/1-\beta-\alpha}\}. u_t^{\gamma}. A_t$

$\rightarrow Y_t/L_t = S_K^{\alpha/1-\alpha-\beta} \; . \; S_H^{\beta/1-\alpha-\beta} \; . \; u_t^{\gamma\{\alpha+\beta]/1-\alpha-\beta} \; . \; (n+g+\delta)^{-\{\alpha+\beta]/1-\alpha-\beta} \; . \; u_t^{\gamma}. A_t \rightarrow$

(4.11b) $Y_t/L_t = S_K^{\alpha/1-\alpha-\beta} \; . \; S_H^{\beta/1-\alpha-\beta} \; . \; u_t^{\gamma/1-\alpha-\beta} \; . \; (n+g+\delta)^{-\{\alpha+\beta]/1-\alpha-\beta} \; . \; A_t$

Remember from Definitions above that u = U/AL, which implies that:

$Y_t/L_t = S_K^{\alpha/1-\alpha-\beta} \; . \; S_H^{\beta/1-\alpha-\beta} \; . \; (U_t/A_tL_t)^{\gamma/1-\alpha-\beta} \; . \; (n+g+\delta)^{-\{\alpha+\beta]/1-\alpha-\beta} \; . \; A_t \rightarrow$

$Y_t/L_t = S_K^{\alpha/1-\alpha-\beta} . S_H^{\beta/1-\alpha-\beta} .(U_t/L_t)^{\gamma/1-\alpha-\beta} . (n+g+\delta)^{-\{\alpha+\beta]/1-\alpha-\beta} . A_t^{(1-\alpha-\beta)/\gamma} . A_t \rightarrow$

Equation (4.18):

$$Y_t/L_t = S_K^{\alpha/1-\alpha-\beta} . S_H^{\beta/1-\alpha-\beta} .(U_t/L_t)^{\gamma/1-\alpha-\beta} . (n+g+\delta)^{-\{\alpha+\beta]/1-\alpha-\beta} . A_t^{(1-\alpha-\beta+\gamma)/\gamma}$$

Taking natural logarithims, equation (4.18) becomes

$$(4.18a)\ \text{Ln}\,(Y_t/L_t) = (\alpha/1-\alpha-\beta)\ \text{Ln}\ S_{Kt} + (\beta/1-\alpha-\beta)\ \text{Ln}\ S_{Ht} - [(\alpha+\beta)\,/\,(1-\alpha-\beta)]\ \text{Ln}\,(n_t+g+\delta) + \gamma/(1-\alpha-\beta)\ \text{Ln}(U_t/L_t) + (1-\alpha-\beta+\gamma)/\gamma\ \text{Ln}\ A_t$$

which is the basic prototype for the alternative specifications of the model.

*Two Possibilities*:

Now, with respect to technology, we can assume it completely exogenous and dependent only on time as in equation (4.2) above where $A_t = A_0 e^{gt}$. In that case,

$$(4.2a)\ \text{Ln}\ A_t = \text{Ln}\ A_0 + gt .$$

Or we can assume the level of technology is dependent on human and urban capital along with time as in (4.5a) $A_t = A_0 e^{gt} H_t^a U_t^b e^{cHU}$, and taking logarithms we obtain :

$$(4.5b)\ \ln A_t = \ln A_0 + gt + c_1 \ln H_t + c_2 \ln U_t + c_3 H_t U_t$$

In what follows, we will explore the econometric specifications of both possibilities.

If we assume (4.2a), then

$$(4.18a)\ \text{Ln}\,(Y_t/L_t) = (\alpha/1-\alpha-\beta)\ \text{Ln}\ S_K + (\beta/1-\alpha-\beta)\ \text{Ln}\ S_H - [(\alpha+\beta)\,/\,(1-\alpha-\beta)]\ \text{Ln}\,(n+g+\delta) + \gamma/(1-\alpha-\beta)\ \text{Ln}\,(U_t\,/L_t) + (1-\alpha-\beta+\gamma)/\gamma\ \text{Ln}\ A_t$$

becomes after substituting (4.2a) into (4.18a),

$$(4.18b)\ \text{Ln}\,(Y_t/L_t) = (\alpha/1-\alpha-\beta)\ \text{Ln}\ S_K + (\beta/1-\alpha-\beta)\ \text{Ln}\ S_H - [(\alpha+\beta)\,/\,(1-\alpha-\beta)]\ \text{Ln}\,(n+g+\delta) + \gamma/(1-\alpha-\beta)\ \text{Ln}\,(U_t\,/L_t) + (1-\alpha-\beta+\gamma)/\gamma\ \text{Ln}\ A_0 + (1-\alpha-\beta+\gamma)/\gamma\, gt$$

(Note that following the tradition in the growth literature, we drop the subscript t on the variables $S_K$, $S_H$, and n)

This will be the first equation to estimate, with $(1-\alpha-\beta+\gamma)/\gamma\ \text{Ln}\ A_0$ serving as the constant which when estimated under a fixed effects procedure can produce country effects obviously augmented by the output elasticity with respect to all of the three sorts of capital. $(U_t\,/L_t)$ is urban capital per capita.

However, if the level of technology is dependent on the level of human and urban capital in a country or region as in (4.5b) substituting it back into (4.18a) gives:

$$(4.18c)\ \text{Ln}\,(Y_t/L_t) = (\alpha/1-\alpha-\beta)\ \text{Ln}\ S_K + (\beta/1-\alpha-\beta)\ \text{Ln}\ S_H - [(\alpha+\beta)\,/\,(1-\alpha-\beta)]\ \text{Ln}\,(n+g+\delta) + \gamma/(1-\alpha-\beta)\ \text{Ln}\,(U_t\,/L_t) + (1-\alpha-\beta+\gamma)/\gamma\ \text{Ln}\ A_0 + (1-\alpha-\beta+\gamma)/\gamma\, gt + (1-\alpha-\beta+\gamma)/\gamma\, c_1\ \text{Ln}\ H_t + (1-\alpha-\beta+\gamma)/\gamma\, c_2\ \ln U_t + (1-\alpha-\beta+\gamma)/\gamma\, c_3\, H_t\, U_t$$

Equation (4.18b) is different from (4.18a) in that levels of human and urban capital operate as shifters of the technology function and therefore of the whole production function. An interaction term $H_tU_t$ gauges the additional effect if any of the interaction of human and urban capital.

Equations (4.18a) and (4.18b) can be tested for a restricted version in which the sum of the first two coefficients minus the third should yield an estimate not significantly different from zero.

*Estimating Agglomeration Effects: Two More Specifications*

So far we've assumed urbanization a variable outside the system affecting the determination of the steady-states of physical and human capital, as in equations (4.15) and (4.16), but not in fact being affected by them. No steady state for the level of urban capital was determined or made use of. This was actually done to develop specifications (4.18a) and (4.18b) above where urbanization enters the picture as $U_t$.

By contrast, if the steady-states of k and h, $k^*$ and $h^*$ respectively are substituted into equation (4.17) $u_t = [(S_\mu\ k_t^\alpha\ h_t^\beta\ ) / (n + g + \delta)\ ]^{1/1-\gamma}$, then we obtain the steady-state value for urban capital per unit of effective labor,

(4.17a) $u_t^* = [(S_\mu^{1-\alpha-\beta}\ S_K^\alpha\ S_H^\beta\ ) / (n + g + \delta)\ ]^{1/1-\alpha-\beta-\gamma}$

Substituting (4.17a) into (4.11b):

$$Y_t/L_t = S_K^{\alpha/1-\alpha-\beta}\ .\ S_H^{\beta/1-\alpha-\beta}\ .\ u_t^{\gamma\ /\ 1-\alpha-\beta}\ .\ (n+g+\delta)^{-\{\alpha+\beta]\ /\ 1-\alpha-\beta}\ .\ A_t \Rightarrow$$

$$Y_t/L_t = S_K^{\alpha/1-\alpha-\beta} .S_H^{\beta/1-\alpha-\beta}.[(S_\mu^{1-\alpha-\beta}S_K^\alpha S_H^\beta)/(n+g+\delta)]^{\gamma\ /\ (1-\alpha-\beta\ )(1-\alpha-\beta-\gamma)}$$
$$.(n+g+\delta)^{-\{\alpha+\beta]\ /\ 1-\alpha-\beta} .A_t \Rightarrow$$

(4.19) $Y_t/L_t = S_K^{\alpha/1-\alpha-\beta-\gamma} .S_H^{\beta/1-\alpha-\beta-\gamma} .S_\mu^{\gamma/(1-\alpha-\beta-\gamma)}\ .\ (n+g+\delta)^{-\{\alpha+\beta]\ /\ 1-\alpha-\beta-\gamma}\ .\ A_t \Rightarrow$

$$(4.19a)\ \ln (Y_t/L_t) = \alpha/(1-\alpha-\beta-\gamma) \text{ Ln } S_K + \beta/(1-\alpha-\beta-\gamma) \text{ Ln } S_H + \gamma/(1-\alpha-\beta-\gamma) \text{ Ln } S_\mu - [(\alpha+\beta+\gamma) / (1-\alpha-\beta-\gamma)] \text{ Ln } (n+g+\delta) + \text{Ln } A_t$$

Again if $\text{Ln } A_t = \text{Ln } A_0 + gt$ ➔

$$(4.19b)\ \ln (Y_t/L_t) = \alpha/(1-\alpha-\beta-\gamma) \text{ Ln } S_K + \beta/(1-\alpha-\beta-\gamma) \text{ Ln } S_H + \gamma/(1-\alpha-\beta-\gamma) \text{ Ln } S_\mu - [(\alpha+\beta+\gamma) / (1-\alpha-\beta-\gamma)] \text{ Ln } (n+g+\delta) + \text{Ln } A_0 + gt$$

Or else if $\ln A_t = \ln A_0 + gt + c_1 \ln H_t + c_2 \ln U_t + c_3 H_t U_t$ ➔

$$(4.19c)\ \ln (Y_t/L_t) = \alpha/(1-\alpha-\beta-\gamma) \text{ Ln } S_K + \beta/(1-\alpha-\beta-\gamma) \text{ Ln } S_H + \gamma/(1-\alpha-\beta-\gamma) \text{ Ln } S_\mu - [(\alpha+\beta+\gamma) / (1-\alpha-\beta-\gamma)] \text{ Ln } (n+g+\delta) + \text{Ln } A_0 + gt + c_1 \ln H_t + c_2 \ln U_t + c_3 H_t U_t$$

where (4.19b) and (4.19c) are the third and fourth equations to estimate. They differ from (4.18b) and (4.18c) not only in the interpretation of the coefficients, but also in the nature of the variables included. Instead of $U_t / L_t$ , $S_\mu$ the share of output devoted to building urban capital is the major urban explanatory variable here. The level of urbanization, $U_t$, used in (4.18c) and (4.19c) along with the level of human capital, $H_t$, act only as shifters.

Furthermore, a restricted version of equations (4.19b) and (4.19c) can test whether the sum of the first three coefficients minus the fourth coefficient is equal to zero.

The country effects in equations (4.19) are much more straightforward to recover and interpret since they are not intermingled with the output elasticities with respect to capital, education, and urbanization as in equations (4.18b) and (4.18c).

Restricted Versions:

But to recover estimates of the output elasticities with respect to all three kinds of capital, K, H, and U, we need to estimate restricted versions of equations (4.18b) and (4.18c), and (4.19b) and (4.19c).

Thus (4.18b) can be rewritten as:

$$(4.18d)\quad \text{Ln}\,(Y_t/L_t) = (\alpha/1-\alpha-\beta)\,[\text{Ln}\,S_K - \text{Ln}\,(n+g+\delta)] + (\beta/1-\alpha-\beta)\,[\text{Ln}\,S_H - \text{Ln}\,(n+g+\delta)] + \gamma/(1-\alpha-\beta)\,\text{Ln}\,(U_t/L_t) + (1-\alpha-\beta+\gamma)/\gamma\,\text{Ln}\,A_0 + (1-\alpha-\beta+\gamma)/\gamma\,gt$$

Similarly, we can rewrite (4.18c) as:

$$(4.18e)\quad \text{Ln}\,(Y_t/L_t) = (\alpha/1-\alpha-\beta)\,[\text{Ln}\,S_K - \text{Ln}\,(n+g+\delta)] + (\beta/1-\alpha-\beta)\,[\text{Ln}\,S_H - \text{Ln}\,(n+g+\delta)] + \gamma/(1-\alpha-\beta)\,\text{Ln}\,(U_t/L_t) + (1-\alpha-\beta+\gamma)/\gamma\,\text{Ln}\,A_0 + (1-\alpha-\beta+\gamma)/\gamma\,gt + (1-\alpha-\beta+\gamma)/\gamma\,c_1\,\text{Ln}\,H_t + (1-\alpha-\beta+\gamma)/\gamma\,c_2\,\text{ln}\,U_t + (1-\alpha-\beta+\gamma)/\gamma\,c_3\,H_t\,U_t$$

The same applies to (4.19b) and (4.19c) which we can rewrite respectively as:

$$(4.19d)\quad \text{ln}\,(Y_t/L_t) = \alpha/(1-\alpha-\beta-\gamma)\,[\text{Ln}\,S_K - \text{Ln}\,(n+g+\delta)] + \beta/(1-\alpha-\beta-\gamma)\,[\text{Ln}\,S_H - \text{Ln}\,(n+g+\delta)] + \gamma/(1-\alpha-\beta-\gamma)\,[\text{Ln}\,S_\mu - \text{Ln}\,(n+g+\delta)] + \text{Ln}\,A_0 + gt_t$$

$$
\begin{aligned}
(4.19e)\ \ln (Y_t/L_t) = {} & \alpha/(1-\alpha-\beta-\gamma)\,[\mathrm{Ln}\, S_K - \mathrm{Ln}\,(n+g+\delta)] \\
& +\beta/(1-\alpha-\beta-\gamma)\,[\mathrm{Ln}\, S_H - \mathrm{Ln}\,(n+g+\delta)] \\
& +\gamma/(1-\alpha-\beta-\gamma)\,[\mathrm{Ln}\, S_\mu - \mathrm{Ln}\,(n+g+\delta)] \\
& + \mathrm{Ln}\, A_0 + gt_t + c_1 \ln H_t + c_2 \ln U_t + c_3 H_t U_t
\end{aligned}
$$

A major difference between the pair (4.18d) and (4.18e) and the pair (4.19d) and (4.19e) is the fact that for the latter three restrictions are imposed whereas for the former there are only two restrictions. In either case, the estimated coefficients are set equal to their value in terms of $\alpha$, $\beta$, and $\gamma$ that is predicted by the equations (4.18d), (4.18e), (4.19d), or (4.19e). Then we solve for the specific numerical values of $\alpha$, $\beta$, and $\gamma$ in a system of two-equations two-unknowns in the case of two restrictions, and three-equations three-unknowns in the case of the three restrictions.

For example suppose in one of the equations (4.18d) or (4.18e) the estimates of the restricted coefficients $(\alpha/1-\alpha-\beta)$ and $(\beta/1-\alpha-\beta)$ was $(\alpha/1-\alpha-\beta) = (\beta/1-\alpha-\beta) = 1$. Then solving for $\alpha$ and $\beta$ simultaneously we get $\alpha = \beta = 1/3$. And if in that same regression the value of $\gamma/(1-\alpha-\beta)$ was equal to ½, then using the values for $\alpha$ and $\beta$ obtained we can get a value of $\gamma$ equal to 1/6.

By the same token we can obtain values for $\alpha$, $\beta$, and $\gamma$ from the coefficients of the restricted regressions (4.19d) and (4.19e) by solving simultaneously for the three of them. Then we can consider if the output elasticities obtained are plausible.

# CHAPTER V

# EMPIRICAL ISSUES

*Definition of the Variables Used:*

The following are the four basic equations from the previous chapter to be estimated. These are (4.18b), (4.18c), (4.19b) and (4.19c) respectively:

(4.18b) $\text{Ln}\,(Y_t/L_t) = (\alpha/1-\alpha-\beta)\,\text{Ln}\,S_K + (\beta/1-\alpha-\beta)\,\text{Ln}\,S_H$
$- [(\alpha+\beta)\,/\,(1-\alpha-\beta)]\,\text{Ln}\,(n+g+\delta) + \gamma/(1-\alpha-\beta)\,\text{Ln}\,(U_t\,/L_t)$
$+ (1-\alpha-\beta+\gamma)/\gamma\,\text{Ln}\,A_0 + (1-\alpha-\beta+\gamma)/\gamma\,gt$

Or else if $\ln A_t = \ln A_0 + gt + c_1 \ln H_t + c_2 \ln U_t + c_3 H_t U_t$, as in (4.5b) ➔

(4.18c) $\text{Ln}\,(Y_t/L_t) = (\alpha/1-\alpha-\beta)\,\text{Ln}\,S_K + (\beta/1-\alpha-\beta)\,\text{Ln}\,S_H$
$- [(\alpha+\beta)\,/\,(1-\alpha-\beta)]\,\text{Ln}\,(n+g+\delta) + \gamma/(1-\alpha-\beta)\,\text{Ln}\,(U_t\,/L_t)$
$+ (1-\alpha-\beta+\gamma)/\gamma\,\text{Ln}\,A_0 + (1-\alpha-\beta+\gamma)/\gamma\,gt + (1-\alpha-\beta+\gamma)/\gamma\,c_1\,\text{Ln}\,H_t$
$+ (1-\alpha-\beta+\gamma)/\gamma\,c_2 \ln U_t + (1-\alpha-\beta+\gamma)/\gamma\,c_3\,H_t\,U_t$

(4.19b) $\text{Ln}\,(Y_t/L_t) = \alpha/(1-\alpha-\beta-\gamma)\,\text{Ln}\,S_K + \beta/(1-\alpha-\beta-\gamma)\,\text{Ln}\,S_H + \gamma/(1-\alpha-\beta-\gamma)\,\text{Ln}\,S_\mu$
$- [(\alpha+\beta+\gamma)\,/\,(1-\alpha-\beta-\gamma)]\,\text{Ln}\,(n+g+\delta) + \text{Ln}\,A_0 + gt$

Or else if $\ln A_t = \ln A_0 + gt + c_1 \ln H_t + c_2 \ln U_t + c_3 H_t U_t$, as in (4.5b) ➔

(4.19c) $\text{Ln}\,(Y_t/L_t) = \alpha/(1-\alpha-\beta-\gamma)\,\text{Ln}\,S_K + \beta/(1-\alpha-\beta-\gamma)\,\text{Ln}\,S_H + \gamma/(1-\alpha-\beta-\gamma)\,\text{Ln}\,S_\mu$
$- [(\alpha+\beta+\gamma)\,/\,(1-\alpha-\beta-\gamma)]\,\text{Ln}\,(n+g+\delta)$
$+ \text{Ln}\,A_0 + gt + c_1 \ln H_t + c_2 \ln U_t + c_3\,H_t\,U_t$

where equations (4.18) are different from equations (4.19) in that the *level* of per capita urban capital is used instead of the share of income devoted to building urban capital in (4.18). The difference between the b specifications and the c specifications in equations (4.18) and (4.19) is that the b's assume the level of technology independent of human and urban capital, whereas the c's assume the level of technology dependent on the levels of human and urban capital.

Upon examining the equations above, we note that the list of variables included are:

1 - Ln (Y/L): The log of real per capita GDP using 1985 international prices, where Y is income and L is proxied by population instead of labor. This follows Nazrul Islam (1995) who made the choice because of data availability, and to make the model more representative of the standard of living as opposed to productivity.

2 - Ln $S_K$:: The share of income devoted to saving, or to building physical capital, since saving are assumed equal to investment. Ln $S_K$ is always proxied in the literature by the log of the ratio of real domestic investment (private plus public) to real GDP. This variable is expected to be positively related to real per capita GDP.

3 - Ln $S_H$: The share of income devoted to building human capital. There is no consensus on what to use here. MRW and Nazrul Islam used (the log of) enrollment rates multiplied by eligible population to get the percentage of the working age population that is in secondary school. Both consider their proxy lacking. I use the log of the ratio of total nominal government expenditure on education to GDP. This variable is expected to be positively related to real per capita GDP.

4 - Ln $S_\mu$: The share of income devoted to building urban capital. The proxy for this variable is the log of the proportion of the total population residing in urban agglomerations which are defined as agglomerations that had a population more than 750,000 in 1990, along the same lines measuring the shares of income going to physical and human capital with the proportions of saving to income, and enrolled school children to those eligible. This variable is expected to be positively related to real per capita GDP.

5 - Ln $(n+g+\delta)$ : The log of the growth rates of population, technology, and depreciation respectively, where the latter two are presumed to be jointly equal to 5% across all the countries in the sample, with $g=0.02$ and $\delta=0.03$. This variable is expected to be negatively related to real per capita GDP.

6 - Ln $A_0$ : The initial state of technology represented by the estimated intercept term of the equation in question. This term will be allowed to vary across countries under the fixed effects approach using LSDV. Then these effects are expected to be a significant positive determinant of real per capita GDP.

7 - gt : t is a time variable ranging from 1 to 6, where the year 1960=1 and 1985=6...This term was ignored by MRW because they estimated a cross-section consisting of an average for the years 1960-1985. So their t was always equal to one and hence the intercept became Ln $A_0$ + g. By using panel data, and because theory dictates t be an independent variable as in the equations above, we are afforded the opportunity to estimate g the exogenous growth rate of technology and to compare it with the assumptions made earlier about the value of g, which is expected to be positively related to real per capita GDP.

8 - Ln$H_t$ : The log of the stock of human capital H proxied by the log of the average years of schooling in the total population over 25. When significant, this variable is expected to be positively related to real per capita GDP.

9- Ln $H_2$: The log of the stock of human capital H proxied by the log of the average years of schooling in the total population over 25 deflated by the pupil/teacher ratio in primary school to account for the quality of education. When significant, this variable is expected to be positively related to real per capita GDP.

10 - Ln $U_t$: The log of the stock of urban capital U proxied by population residing in urban agglomerations above 750 thousand in 1990 as a proportion of total urban population. In one variation, U is defined as the log of the proportion of total population living in urban agglomerations above 750 thousand in 1990. If significant at all, this variable is expected to be positively related to per capita GDP.

11- $H_t$ $U_t$: An interaction term obtained by multiplying the average years of schooling of the total population over 25 by the proportion of the urban population living in agglomerations above 750 thousand in 1990. This interaction term is meant to capture the Rauch effect. Rauch (1993) asserted that higher geographic concentrations of human capital lead to higher income. The idea is to see if this effect generalizes from SMSAs to countries. This variable is expected to be positively related to per capita GDP.

12 - Ln ($U_t/L_t$): The log of the level of urban capital per capita. Since U was already defined above as urban population residing in urban agglomerations above 750 thousand in 1990, and L in Y/L was defined as population, it would follow that Ln ($U_t/L_t$) be defined as the log of the ratio of proportion of urban population residing in urban agglomerations above 750 thousand in 1990 divided by population L. (In fact this ratio was multiplied by a hundred since U is a percentage expressed in the double digits and L is expressed minus the last three digits). This variable is expected to be positively related to per capita GDP.

*More on the Meaning of the Variable Ln ($U_t/L_t$):*

The variable Ln ($U_t/L_t$) was not chosen in an ad hoc fashion as a proxy for urban capital but was dictated directly by theory from the previous chapter. As such it represents the urban proxy in the aggregate production function when the level of urban capital rather than the share of income going to urban capital is used, which generated equations (4.18). In fact ($U_t/L_t$) represents urban capital per capita, and its coefficient in equations (4.18) represents the correlation between urban capital per capita and income per capita holding everything else constant.

Since the definition of the variable ($U_t/L_t$) is the proportion of urban population in large urban agglomeration divided by total population, the intuitive appeal of this variable might not be readily obvious. In reality this measure is meant to capture the level of agglomeration externalities as a ratio of the population. As such, it enters the aggregate production function as a separate input. The idea is that the higher the urban capital or agglomeration externalities per population, the higher the standard of living, given the constancy of other inputs.

Another way to look at the variable ($U_t / L_t$) is to examine its relationship to other urban variables like $S_\mu$. Since $S_\mu$, the share of income going to urban capital is equal to the proportion of total population residing in urban agglomerations of 750 thousand and above, let's denote as $S_\mu$ = Agg/L to express the definition of $S_\mu$ in a fraction, where Agg is the population of agglomerations above 750 thousand, and L is total population.

U is the proxy for urban capital where U = Agg/Urb, and where Agg is again the population of urban agglomerations above 750 thousand, and Urb is just the population of urban areas in general.

The above implies that U/L = {Agg/Urb}/L ➔

U/L = (Agg/L).(1/Urb) ➔

**U/L = $S_\mu$ / Urb**

Thus the last formulation of U/L indicates that the level of urban capital per capita is also equal to the share of income going to urbanization spread over the urban population. This reformulation of U/L might be important in interpreting the economic implications of the coefficients estimated . It also draws a linkage between equations (4.18) and equations (4.19), since the latter use the share of income going to urban capital $S_\mu$ . In the meantime we note that the level of urban capital per capita, which is hypothesized to have a positive impact on economic growth declines with increases in total urban population, but increases with $S_\mu$ which is the proportion of total population living in huge urban agglomerations.

In other words if the empirical analysis supports the hypothesis of a positive relationship between economic growth on one hand and U/L and $S_\mu$ on the other, we will see later that this is consistent with the hypothesis that urban concentration increases non-linearly with economic development. In the early stages of development as population concentrates in a few urban agglomerations, that correlates positively with economic growth. But sheer increases in urban population otherwise do not necessarily generate economic growth, and might even depress it, thus generating the urban bias effect frequently discussed in the literature.

*Description and Sources of Data:*

For each of the variables listed above as many observations as possible were collected for as many countries as possible for as many years as possible. The result was a panel data set for 63 countries that includes the years 1960, 65, 70, 75, 80, and 85 which is the same time frame MRW and Nazrul Islam and others have used.

GDP per capita, ratio of real investment to real GDP, and the ratio of total nominal government expenditure on education to nominal GDP were each five-year averages obtained from the Barro-Lee data set, the 1994 Revision. The measure of the average years of schooling in the total population over 25 years old in the years 1960, 65, 70, 75, 80, and 85 (not averages), was also obtained from the Barro-Lee data set, the 1994 Revision.

The pupil/ teacher ratio in primary school was obtained from the Statistical Yearbook of UNESCO, 1994.

The growth rate of population, population, the percentage of urban population residing in urban agglomerations with 750 thousand or more inhabitants in 1990, and the percentage of total population residing in urban agglomerations with 750 thousand or more inhabitants in 1990 were all obtained from Word Urbanization Prospects: The 1994 Revision, UN, New York, 1995.

After that several other source were used to fill in the blanks where missing observations occurred. Some of those sources are different issues of: The Statistical Yearbook of the UN, Demographic Yearbook of the UN, International Trade Statistics of the UN, and World Tables of the World Bank 1995. Still, and in spite of extensive efforts to fill in the gaps, some observations for some countries are missing. Thus instead of having a complete matrix of 63 x 6 = 378 observations, a maximum of 374 and a minimum of about 345 were available for any given regression.

The countries included in the sample in alphabetical order are: Algeria, Argentina, Australia, Austria, Bangladesh, Belgium, Bolivia, Brazil, Cameroon, Canada, Chile, Columbia, Congo, Costa Rica, Denmark, Dominican Republic, Ecuador, Finland, France, Germany, Ghana, Greece, Guatemala, Haiti, Hong Kong, India, Indonesia, Iran, Iraq, Ireland, Italy, Japan, Jordan, Malaysia, Mexico, Mozambique, Netherlands, New Zealand, Nicaragua, Pakistan, Panama, Peru, Philippines, Portugal, Republic of (South) Korea, Senegal, Singapore, Spain, Sudan, Sweden, Syria, Thailand, Tunisia, Turkey, Uganda, United Kingdom, United Republic of Tanzania, United States of America, Uruguay, Venezuela, Yugoslavia, Zambia, and Zimbabwe.

In collecting and constructing data sets of this sort in other studies, some have created criteria like excluding formerly socialist countries, countries that are oil-producers, countries that are city-states like Hong Kong or Singapore, or countries that had a population deemed too small. No attempt at exclusion was made here because the forces affecting economic growth are assumed to affect all countries equally.

As it turned out, however, the only ex-socialist country in the sample was Yugoslavia, which was even then relatively less closed to the West than other ex-socialist states, say like Albania. In the future it would be interesting to see if including a large number of ex-socialist observations would alter the results significantly, and to see whether an ex-socialist dummy would be significant or not.

Also, even though Algeria, Iraq, and Iran which are oil-producing countries are included in the sample, these are countries for which many social, economic, and demographic patterns were established long before the oil boom which took place only half-way through our period of 1960-85. Economies that arose significantly only on the back of the oil boom like Saudi Arabia, Kuwait, United Arab Emirates, Brunei, Oman, and such are not in the sample, even though if their data were more complete, they would have been included and an oil dummy might have been added.

City-states like Hong Kong and Singapore were not removed from the sample. Furthermore, of all the countries in the sample only one happened to have a population of less than 2 million in 1985, and that was Congo which had a population of 1,923 million in 1985. Again, if being a small country should make a difference in the patterns of economic growth, that should probably be due trade openness and urban concentration.

Moreover, one implicit bias in the sample, and every other one in this kind of study, is that advanced industrialized economies always have more and better data than other countries. Advanced economies, however, represent less than one-third of the sample. Africa is represented with 12 countries, Asia with 16, Central and South America also with 16, whereas Europe is represented with 15, with the United States, Canada, Australia, and New Zealand being the remaining countries. Among the European countries are Yugoslavia, Ireland, Spain, and Portugal, where the latter two were classified as third world until 1970, and the first two have some third world characteristics until today. On the other hand, Asia includes Japan, and many newly industrialized countries (NICs). Finally Africa includes northern countries like Algeria that have devoted a comparatively much larger share of GDP to investment (South Africa is not in the sample), and Tunisia which is relatively more westernized, in addition to southern countries like Zambia, and Zimbabwe.

General statistics on the variables in the data set can be gleaned from Tables I and II which have been set aside separately on the next page for easy reference.

Table I: Summary Statistics on the Data Set

| Variable | N | Mean | Std. Dv. |
|---|---|---|---|
| $Ln (Y_t/L_t)$ | 375 | 7.96 | 0.91 |
| $Ln S_\kappa$ | 376 | -1.74 | 0.62 |
| $Ln S_H$ | 370 | -3.35 | 0.46 |
| $Ln S_\mu$ | 378 | 2.83 | 0.8 |
| $Ln(n+g+\delta)$ | 378 | 1.92 | 0.16 |
| $Ln (U_t/L_t)$ | 378 | -1.15 | 1.37 |
| $Ln H_t$ | 371 | 1.22 | 0.79 |
| $Ln H_2$ | 364 | -2.2 | 1.04 |
| $Ln U_t$ | 378 | 3.69 | 0.42 |
| $H_tU_t$ | 371 | 189.38 | 149.07 |

Observations are ordered in a panel format with N=63 countries and T=6 time periods between 1960 and 1985. When observations do not add up to 378, that implies missing observations.

Table II: Correlations Between Variables in the Models

| | Ln(Y/L) | Ln $S_K$ | Ln $S_H$ | Ln $S_\mu$ | Ln(n+g+δ) | Ln($U_t$/$L_t$) | Ln$H_t$ | Ln$H_2$ | Ln$U_t$ | $H_tU_t$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Ln(Y/L) | 1 | 0.6 | 0.485 | 0.62 | -0.67 | -0.092 | 0.74 | 0.79 | -0.093 | 0.61 |
| Ln $S_K$ | 0.0001 | 1 | 0.34 | 0.425 | -0.43 | -0.096 | 0.67 | 0.66 | -0.105 | 0.45 |
| Ln $S_H$ | 0.0001 | 0.0001 | 1 | 0.22 | -0.24 | 0.03 | 0.36 | 0.38 | -0.24 | 0.23 |
| Ln $S_\mu$ | 0.0001 | 0.0001 | 0.0001 | 1 | -0.28 | 0.2 | 0.57 | 0.54 | 0.47 | 0.72 |
| Ln n+g+δ | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 1 | 0.16 | -0.59 | -0.63 | 0.15 | -0.43 |
| Ln($U_t$/$L_t$) | 0.0734 | 0.0638 | 0.5644 | 0.0001 | 0.0021 | 1 | -0.061 | -0.1 | 0.34 | 0.11 |
| Ln$H_t$ | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.2408 | 1 | 0.96 | -0.044 | 0.71 |
| Ln$H_2$ | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0551 | 0.0001 | 1 | -0.085 | 0.68 |
| Ln$U_t$ | 0.0723 | 0.0406 | 0.0001 | 0.0001 | 0.0026 | 0.0001 | 0.3946 | 0.1046 | 1 | 0.51 |
| $H_tU_t$ | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.023 | 0.0001 | 0.0001 | 0.0001 | 1 |

Numbers to the right of diagonal are correlation coefficients, to the left of diagonal are levels of significance.

## **Econometric Approach**:

Following Nazrul Islam (1995), OLS will first be applied to the pooled (panel) data, then the results will be compared to those obtained from applying OLS with country dummies (LSDV).

According to Greene (1993): "...researchers have been able to use time-series cross-sectional data to examine issues that could not be studied in either cross-sectional or time-series settings alone" (p.464). An interesting and relevant example of this has to do with separating the effects of technological change and economies of scale in production functions. Cross-sectional data can only measure the economies of scale effect, whereas time-series measures the combined effect of both without separating them out. Other benefits of panel data numerated in Alwosabi (1996) were that they increased the degrees of freedom from N to NT, where N is the size of the cross-section and T is the number of time periods (p. 80). Also, Alwosabi adds that "Panel data reduces multicollinearity among regressors and thus improves the efficiency of the estimates" (Ibid).

"Furthermore, by allowing testing for country and time effects, panel data provides controls for the effects of missing or unobserved variables that are correlated with explanatory variables" (Ibid). This last point is the most pertinent for the theoretical questions at hand: the same type of problem in the economic growth literature makes it difficult to discern the influence of country-specific technology from that of the other variables in the aggregate production function. That means the error term may not be independent of the exogeneous variables. The initial state of the economy affects the conventional variables in Solow's model like the population growth rate and the saving rate. Disregarding this by assuming a common constant term, relegates the variation in the individual country effects to the error term, and thus injects systematic correlation between independent variables and the error term. And that is a violation of one of the basic assumptions of OLS.

A way to deal with this problem is to use the panel data to estimate the model with LSDV, i.e., least squares dummy variable method, otherwise known as the fixed effects model (FEM). This model assumes a different intercept for each country in the sample. Thus these country effects as they are sometimes called imply that each country has a technology term that is an unknown parameter to be estimated. This is called the within group estimator (Greene 1993). One drawback of the fixed effects approach is that its results are conditional on the sample under observation and thus can't be generalized outside the sample.

Pindyck and Rubinfeld (1981) criticize the LSDV method because they hold that "the use of dummies does not directly identify the variables which might cause the regression line to shift over time and over individuals. The use of dummy variables is an attempt to adjust for important missing information in the model. In doing so, a substantial portion of the error variation can be "explained" without the analyst's obtaining any useful knowledge about the model. Because of this fact , dummy variable coefficients are difficult to interpret" (p.255). In the case of growth models however, a theoretical case has been made for a possible role of individual country effects in explaining the standard of living, since the latter in this context involve culture, technology, institutions, preferences and what have you. This reduces the significance of the criticism advanced by Pindyck and Rubinfeld.

An alternative method to deal with this problem is to estimate a random effects model (REM). This amounts to estimating the regression using GLS, or generalized least squares. Under REM, we view the "individual specific constant terms as randomly distributed across cross-sectional units" (Greene

1993, p. 469). This amounts to taking the estimated base intercept as a reference point, then allowing the intercept for the cross-sectional observations in the sample to jump randomly around that base. Pindyck and Rubinfeld (1981) add that REM assume "that the mean effect of the random time-series and cross-section variables is included in the intercept term and the random deviations about the mean are equated to the error components. The use of dummy variables would force no restrictions on the pattern of shifting regression intercepts, while the error components model would presume that the pattern follows a normal distribution" (p.257)

One advantage of REM is that its results are generalizable outside the sample. Random effects imply the sample is a random sample of a larger population, whereas fixed effects imply the sample is the population by virtue of the effects being in nature fixed. But on the other hand, to pursue random effects, REM implies that the intercept is merely randomly distributed not that there is correlation between unobservable individual effects and the included explanatory variables as FEM assumes. Theoretically speaking, Greene (1993) says that "there is no justification for treating the individual effects as uncorrelated with the other regressors, as is assumed by the random effects model" (p.479).

On that basis, Nazrul Islam (1995) who pioneered the use of individual country effects in growth theory, finds REM totally unsuitable for analyzing economic growth because of its underlying assumption of no correlation between the independent variables and the error term. He states: "it is precisely the fact of correlation that forms the basis of our argumentation for the panel approach" (Islam, p.1138).

In this dissertation, both FEM and REM will be estimated, and a Hausman test will be performed to test the hypothesis of no correlation between the explanatory variables and the country effects.

# CHAPTER VI

# EMPIRICAL RESULTS

*The Basic Solow Model Revisited :*

Applying OLS to the panel data at hand to estimate the basic Solow equation without the inclusion of human capital or any other additions, we estimate the coefficients of the textbook Solow model:

$$\text{Ln } (Y_t/L_t) = \text{Ln } A_0 + gt + \alpha/(1-\alpha) \text{ Ln } S_K - \alpha/(1-\alpha) \text{ Ln } (n+g+\delta)$$

which restricted is:

$$\text{Ln } (Y_t/L_t) = \text{Ln } A_0 + gt + (\alpha/1-\alpha) [\text{Ln } S_K - \text{Ln } (n+g+\delta)]$$

Table III: Estimation of Textbook Solow Model

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | Restricted |
|---|---|---|
| Constant | 13.91 (35.71) | 10.82 (56.82) |
| t | 0.09 (5.091) | 0.11 (5.89) |
| Ln $S_K$ | 0.6 (10.96) | |
| Ln $(n+g+\delta)$ | - 2.71 (-12.89) | |
| [Ln $S_K$ – Ln $(n+g+\delta)$] | | 0.89 (18.73) |
| | | $\alpha$ = .47(35.28) |
| Adj R-sq | 0.59 | 0.51 |
| F-Value | 182.412 | 194.03 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

*Test for Internal Restriction: $F = 79.3 > F_{0.01\text{ level}}$ → reject null that restriction holds.

Thus just by using the data above to obtain results for the textbook Solow model without including human capital or implementing fixed effects, we obtain coefficients for investment and population growth exhibiting the expected signs and magnitudes. The implied $\alpha = .47$ which is too large by empirical and conventional standards, is somewhat smaller than the $\alpha = .6$ and .59 that MRW obtain at this stage, or the $\alpha = .83$ and .77 that Nazrul Islam gets.

It is important to note that unlike MRW, the variable t, for time periods, does not vanish since we have six time periods not one. They did a single cross section for averages of the years 1960-85, and so their t was equal to one and thus the term gt became g and was subsumed under the constant term Ln $A_0 + g = a$.

And while Nazrul Islam used panel data to estimate the equation above, he had lagged real per capita GDP as one of the independent variables, since he was interested mainly in the question of convergence which remains tangential for this study. Furthermore, Islam does not report results for the independent time variable t in his Table II where the results of the pooled regression were reported, even though the inclusion of that variable is dictated by the growth equation when more than one time period is under examination.

The $\alpha$ of .47 estimated above remains quite high by conventional standards. A theoretical implication of a high $\alpha$ is that convergence will be slow because the formula for convergence is:

$\lambda = (n+g+\delta)(1-\alpha)$. Hence if $\alpha$ is high, the parameter of convergence $\lambda$ will be low. Estimated values of $\lambda$ in the literature for the textbook Solow model at this stage validate this analysis.

*The MRW Model Revisited:*

Adding human capital to the standard Solow model as MRW did, then applying OLS, without using fixed or random effects, we estimate:

$$(6.1)\quad \text{Ln}\,(Y_t/L_t) = \text{Ln}\,A_0 + gt + (\alpha/1-\alpha-\beta)\,\text{Ln}\,S_K + (\beta/1-\alpha-\beta)\,\text{Ln}\,S_H - [(\alpha+\beta)/(1-\alpha-\beta)]\,\text{Ln}\,(n+g+\delta)$$

which in restricted form is:

$$(6.1a)\quad \text{Ln}\,(Y_t/L_t) = \text{Ln}\,A_0 + gt + (\alpha/1-\alpha-\beta)\,[\text{Ln}\,S_K - \text{Ln}\,(n+g+\delta)] + (\beta/1-\alpha-\beta)\,[\text{Ln}\,S_H - \text{Ln}\,(n+g+\delta)]$$

Comparing the estimates of $\alpha$ and $\beta$ for this equation (see Table III) to those of MRW for both of their large and intermediate samples, we find that they are almost identical. They find $\alpha = .31$ and $.28$ respectively, and $\beta = .29$ and $.3$ respectively. My estimate of $\alpha$ is 0.3 and of $\beta$ is equal to 0.26. Recall also that MRW did not have a time variable t since they were doing a single regression. Moreover, my results were obtained using a different measure for education than they used. Above, the share of income devoted to human capital is measured by the ratio of government expenditure on education to GDP, whereas they use rates of enrollment of those eligible and so does Nazrul Islam.

Table IV : Estimation of Solow Model W/Human Capital

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | Restricted |
|---|---|---|
| Constant | 15.11 (36.64) | 13.33 (39.65) |
| t | 0.06 (3.33) | 0.068 (3.7) |
| Ln $S_K$ | 0.51 (8.94) | |
| Ln $S_H$ | 0.45 (6.57) | |
| Ln $(n+g+\delta)$ | - 2.56 (-12.85) | |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | 0.7 (13.14) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | 0.58 ( 8.23) |
| | | $\alpha = 0.3$ (7.67) |
| | | $\beta = 0.26$ (6.33) |
| Adj R-sq | 0.64 | 0.59 |
| F Value | 161.335 | 178.119 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

*Test of Internal Restriction: $F=45.5 > F_{0.01\ level}$ ➔ can reject null that restriction holds.

By contrast Nazrul Islam's estimates for the pooled regression for his large and intermediate samples are $\alpha = .8$ and .78, and $\beta = .05$ and -.007 respectively.

At this stage though, and if the case for fixed effects had not been effectively made, and we had to make a judgment solely on the basis of the results above, we would have to lean more towards MRW than Nazrul Islam. However, since fixed effects are in order, we have to postpone a judgment until results from that procedure could be procured .

*Nazrul Islam's Fixed Effects* :

Now I try to reproduce Nazrul Islam's model, which is basically the textbook Solow case as above, except that fixed effects are estimated for different countries. This implies each country has a separate intercept term that is supposed to capture the unobservable country effects. Thus we estimate two equations using LSDV, one of which is the textbook Solow model, and the other is the restricted version of that model to obtain the following results:

Table V : Estimation of Textbook Solow Model W/ LSDV

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | Restricted |
|---|---|---|
| Constant | Fixed Effects | Fixed Effects |
| t | 0.12 (19.4) | 0.12 (21.23) |
| Ln $S_K$ | 0.24 (5.97) | |
| Ln (n+g+$\delta$) | - 0.42 (-2.25) | |
| [Ln $S_K$ – Ln (n+g+$\delta$)] | | 0.24 (6.22) |
| | | $\alpha$ = .19 (7.5) |
| Adj R-sq | 0.99 | 0.99 |
| F-Value | 253.205 | 677.205 |

Note: T-values are in parenthesis. Estimates are rounded up to the nearest decimals.

Diagnostics on Table V:

*Test of Internal Restriction: F=0.87 → Can not reject null that restriction holds.

*Test of FE vs OLS: (A different F-test) F=66.5 > $F_{0.01\ level}$ → can reject null that fixed effects are zero.

*Test of FE vs. RE: LM= 0.95 → can not reject null that variance of the errors is zero. Favor FE.

Comparing the above to Islam's results, we estimate $\alpha = .19$ compared to Islam's .44 for his large sample and .46 for his intermediate sample. His estimate of $\alpha$ for the OECD sample is .2 which is practically the same as the implied $\alpha$ of .19 above. However, the fixed effects are significant, and an F test indicates that the fixed effects model is warranted, whereas the Hausman test indicates that the random effects model is not warranted (the results of all random effects estimations are in the appendix).

Nevertheless, it is important to point out here that an $\alpha$ of .44, .46, and .2 is a range that is probably too high. Nevertheless, Islam considers his estimates appropriate. In fact, our first regression indicates an $\alpha = .47$ without the inclusion of human capital or country effects, and that was just the starting point motivating the discussion.

To show human capital irrelevant with country effects, Nazrul Islam estimates the equation of MRW above, i.e., Solow's model with human capital included, with fixed effects. Table VI shows our estimate of the model which uses a different measure of human capital. The results presented below do not support Nazrul Islam's conclusion that human capital is totally irrelevant as an input in the context of the MRW model. On the contrary evidence is present, but not overwhelming that human capital is relevant since the t-value for $\beta$ indicates that it is significant at 0.1 for the one-tailed test.

Table VI: Estimation of Solow Model W/Human Capital & LSDV

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | Restricted |
|---|---|---|
| Constant | Fixed Effects | Fixed Effects |
| t | 0.11 (17.48) | 0.11 (17.99) |
| Ln $S_K$ | 0.23 (5.99) | |
| Ln $S_H$ | 0.11 (2.67) | |
| Ln $(n+g+\delta)$ | - 0.35 (-1.95) | |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | 0.23 (6.1) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | 0.11 (2.76) |
| | | $\alpha = 0.17$ (4.13) |
| | | $\beta = 0.08$ (1.55) |
| Adj R-sq | 0.99 | 0.99 |
| F Value | 327.48 | 324.04 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

Diagnostics on Table VI:

*Test of Internal Restriction: F=0> $F_{0.001\ level}$ ➔ can not reject null that restriction holds.

*FE. vs. OLS: (Another F-test) F= 58.3 > $F_{0.01\ level}$ ➔ can reject null that fixed effects are zero.

*FE. vs. RE: LM=1.026 ➔ can not reject null that variance of errors =0. Favor FE.

(p=.25 is required to accept the null. A relatively high value )

Comparing these results to those obtained by Nazrul Islam, we find that his estimates of $\alpha$ equal to .52 and .49 are off the mark and can not be accepted as reasonable output elasticities with respect to capital. Of course, Nazrul Islam's best implied $\alpha$ is about .44 as long as he is not using the small OECD sample, and that best estimate occurred in the model without human capital.

Overall, his and everybody else's results are much better if one narrows the focus to OECD countries only. But, if the point is to explain cross-country differences in steady-state income, considering OECD countries only does not shed much light on the subject and therefore larger samples are needed.

Going back to Nazrul Islam's results with fixed effects and human capital included, the point above was that his implied $\alpha$s were higher here than in the case without human capital, a burden that he was willing to tolerate in order to demonstrate that the output elasticity with respect to human capital becomes consistently negative throughout all of his three samples, and the t-values for the human capital variable becomes insignificant in the intermediate and the OECD samples. As far as he is concerned, that demonstrates the irrelevancy of human capital as an input. Later he tries to show that human capital is highly positively correlated with the estimated country effects, and should be therefore viewed as a shifter.

However, the implied values of $\alpha = 0.17$ and $\beta = 0.08$ that I find above in Table VI show that Islam's result was dependent on the measure he used for human capital. Using fixed effects, my estimate of $\alpha$ became lower when my measure for human capital was included. Furthermore, the output elasticity with respect to human capital was neither negative nor statistically insignificant as was the case with Islam.

To summarize, in what preceded, the results demonstrated:

1 - that country effects are highly significant.

2- that human capital is relevant in different econometric contexts.

3- that our data set yields results that are highly consistent with those of MRW and Nazrul Islam when used to test the same models. The magnitudes and signs of the saving and population growth rates are as expected.

4 - With the exception of Table IV, where MRW's version is estimated, the estimated exogenous technological growth rate g ranges between .09 and .12 per time period. Given that each time period consists of five years, that gives us a technological growth rate of about 2 percent per year, which is consistent with reality and the assumptions made earlier.

Furthermore, a battery of tests were conducted on each of the models presented above to check for:

a) whether the internal constraints in each equation hold or not, for example, whether the coefficients of the savings and population growth rates are really equal in magnitude and opposite in sign in the basic Solow model as theory predicts,

b) whether LSDV is preferred over OLS or not for each equation, and

c) whether LSDV is preferred over GLS or the random effects model.

The results of the tests above demonstrated the following:

a) In both of the basic Solow and MRW models without fixed or random effects, the internal restrictions on the coefficients have been rejected under the null. On the other hand, when fixed or random effects are estimated, tests could not reject the null that the restrictions of equality of coefficients hold at the 0.01 significance level.

b) In both the restricted and unrestricted versions of the equations above, an F-test indicated that the restrictions that the country effects should be constrained to zeroes have been rejected with a very high degree of significance (at an F equal to 66.5 and 58.3 > $F_{63, 310}$ and $F_{62, 301}$ respectively). Obviously this result favors fixed effects.

c) LM tests on both of the basic Solow and MRW models yielded the result that we can not reject the null hypothesis that the variance of the errors was equivalent to zero. In basic Solow case, the LM was equal to 0.95 and in the MRW case it was equal to 1.026. Since that statistic is assumed to have a Chi-square distribution with one degree of freedom, we can not reject the null of zero variance even at the 0.25 level. This favors the fixed effects model.

Consequently one may conclude that since both fixed effects and the inclusion of human capital are warranted, the best model would combine the contributions of Solow and MRW into one as in Table VI above. In that table, the output elasticities with respect to physical capital is a low .17 and that the output elasticity with respect to human capital is 0.08.

Next I test the models I developed earlier to examine the nature of the relationship between urban agglomerations and economic growth as a natural progression of the models tested so far.

*Urban Agglomerations Equation 4.18(b)*:

For the purposes of a preliminary inquiry, the level of the urban agglomeration per capita will be introduced to estimate equation 18 (b) both in restricted and unrestricted form.

$$(4.18b)\ Ln\ (Y_t/L_t) = (\alpha/1-\alpha-\beta)\ Ln\ S_K + (\beta/1-\alpha-\beta)\ Ln\ S_H$$
$$-\ [(\alpha+\beta)\ /\ (\ 1-\alpha-\beta)]\ Ln\ (n+g+\delta) + \gamma/(1-\alpha-\beta)\ Ln\ (U_t\ /L_t)$$
$$+\ (1-\alpha-\beta+\gamma)/\gamma\ \ Ln\ A_0\ +\ (1-\alpha-\beta+\gamma)/\gamma\ gt$$

which in restricted form becomes

$$Ln\ (Y_t/L_t) = (\alpha/1-\alpha-\beta)\ [Ln\ S_K - Ln\ (n+g+\delta)] + (\beta/1-\alpha-\beta)\ [Ln\ S_H - Ln\ (n+g+\delta)]$$
$$+\ \gamma/(1-\alpha-\beta)\ Ln\ (U_t\ /L_t)$$
$$+\ (1-\alpha-\beta+\gamma)/\gamma\ \ Ln\ A_0\ +\ (1-\alpha-\beta+\gamma)/\gamma\ gt$$

where $S_K$ and $S_H$ are the shares of income going to physical and human capital respectively, n is the population growth rate and $U_t\ /L_t$ is urban capital per capita defined either as metropolitian population or percent of urban population in metropolitan areas per capita. $S_K$ and $S_H$ were proxied by investment and government expenditure as a share of GDP respectively.

Theoretically, a significant change in the equation above is that the estimated intercept term Ln $A_0$ as well as the technological growth rate g now include a constant composed of the parameters of the original production function $\alpha,\beta$, and $\gamma$. The coefficient of time must now be magnified or shrunk in proportion to the coefficient $(1-\alpha-\beta+\gamma)/\gamma$ in order to obtain g.

Table IX: Estimation of Equation 4.18 (b):

Dependent Variable: log of Real GDP per Capita
63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | Restricted |
|---|---|---|
| Constant | 15.09 (37.42) | 13.23 (39.7) |
| t | 0.065 (3.8) | 0.075 (4.08) |
| Ln $S_K$ | 0.5 (8.89) | |
| Ln $S_H$ | 0.4 (5.84) | |
| Ln $(n+g+\delta)$ | - 2.6 (-13.28) | |
| Ln $(U_t / L_t)$ | 0.079 (4.18) | 0.066 (3.28) |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | 0.7 (13.28) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | 0.54 (7.7) |
| | | $\alpha = 0.31$ (7.85) |
| | | $\beta = 0.24$ (5.93) |
| | | $\gamma = 0.03$ (3.31) |
| Adj R-sq | 0.65 | 0.6 |
| F Value | 138.443 | 139.863 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal

*Test of Internal Restriction: $F = 28.38 > F_{0.01\ level}$ ➔ reject null that internal restriction holds.

The results for the coefficients of physical and human capital and the population growth variables shown in Table IX are consistent with those obtained by MRW though a measure of urban capital is included. The output elasticities with respect physical and human capital of .31 and .24 are similar to the ones obtained by MRW without the inclusion of urban capital, except that $\beta( = 0.24)$ is a little lower than the one they estimate. Moreover, the index of urban agglomeration enters significantly into the equation with the expected sign. The output elasticity with respect to urban capital, $\gamma$, is 0.03. This implies that a 100 percent increase in the urbanization index per capita, increases real GDP per capita by 3 percent. These results are preliminary however because we have other theoretical models to consider and we need to consider country effects. These results and the ones in tables (X, XI, and XII) serve as an initial explanatory probe of a pedagogical nature.

Also the only significant change resulting from the introduction of urban agglomeration per capita seems to be a significant decrease in the magnitude of the estimated exogenous rate of technological growth g to less than half a percentage point per time period, from about 11 percent before. Because this change was brought about by the inclusion of our proxy for urban capital, this is perhaps a good time to check whether making technology explicitly a function of the human and urban capital changes the results of Table VIII.

*Urban Agglomerations Equation 4.18(c)*:

$$
\begin{aligned}
(4.18c)\ \text{Ln}\,(Y_t/L_t) = {} & (\alpha/1-\alpha-\beta)\ \text{Ln}\ S_K + (\beta/1-\alpha-\beta)\ \text{Ln}\ S_H \\
& - [(\alpha+\beta) / (1-\alpha-\beta)]\ \text{Ln}\ (n+g+\delta) + \gamma/(1-\alpha-\beta)\ \text{Ln}\ (U_t/L_t) \\
& + (1-\alpha-\beta+\gamma)/\gamma\ \text{Ln}\ A_0 + (1-\alpha-\beta+\gamma)/\gamma\ gt + (1-\alpha-\beta+\gamma)/\gamma\ c_1\ \text{Ln}\ H_t \\
& + (1-\alpha-\beta+\gamma)/\gamma\ c_2\ \ln U_t + (1-\alpha-\beta+\gamma)/\gamma\ c_3\ H_t\ U_t
\end{aligned}
$$

which is the same as equation 4.18(b) above except that technology has been expressed as a function of the intangible inputs human and urban capital. In restricted form, it becomes:

$$\begin{aligned} Ln\,(Y_t/L_t) = {} & (\alpha/1-\alpha-\beta)\,[Ln\,S_K - Ln\,(n+g+\delta)] \\ & + (\beta/1-\alpha-\beta)\,[Ln\,S_H - Ln\,(n+g+\delta)] \\ & + \gamma/(1-\alpha-\beta)\,Ln\,(U_t/L_t) + (1-\alpha-\beta+\gamma)/\gamma\,Ln\,A_0 + (1-\alpha-\beta+\gamma)/\gamma\,gt \\ & + (1-\alpha-\beta+\gamma)/\gamma\,c_1\,Ln\,H_t + (1-\alpha-\beta+\gamma)/\gamma\,c_2\,ln\,U_t + (1-\alpha-\beta+\gamma)/\gamma\,c_3\,H_t\,U_t \end{aligned}$$

where the last three terms will be referred to as the technology shifter. They consist of H, the proxy for the level of human capital, U, the proxy for the level of urban capital, and HU, which is an interaction term meant to capture the effect of the interaction between the levels of urban and human capital. H is defined here as the average years of education of population over 25. U is the proportion of urban population living in large urban agglomerations, and HU is the result of multiplying the two variables $H_t$ and $U_t$.

The analysis of the results will follow later, but for now it is noteworthy that the coefficients of the original MRW variables still exhibit the expected signs. The $\alpha$ has decreased significantly, even though the implied $\beta$ and $\gamma$ still exhibit the same signs and almost the same magnitudes as in 4.18 (b) without the shifter included.

*Urban Agglomerations Equation 4.19(b):*

If we use the share of income devoted to urban capital instead of the level of urban capital as was the case in equations 4.18 (b) and 4.18 ( c) above, the interpretation of the coefficients changes. This is not necessarily a contradictory model, but an alternative way of looking at the same issue. In their article, MRW also discuss the possibility of rewriting the basic Solow model in terms of the level of human capital instead of the share of income going to human capital in equation (12) in their article. They note that "these alternative regressions predict different coefficients on the saving and population growth terms. When testing the augmented Solow model, a primary question is whether the available

Table X: Estimation of Equation 4.18 (c):

Dependent Variable: log of Real GDP per Capita
63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | | | Restricted | |
|---|---|---|---|---|---|
| | (1) | (2) | | (3) | (4) |
| Constant | 13.64 (25.38) | 13.21 (29.89) | | 12.12 (25.66) | 12.11 (34.27) |
| t | 0.027 (1.62) | 0.008 (.48) | | 0.027 (1.57) | 0.0051 (0.3) |
| Ln $H_t$ | 0.142 (1.76) | | | 0.195 (2.35) | |
| Ln $H_2$ | | 0.33 (5.611) | | | 0.4 (6.69) |
| Ln $U_t$ | -0.35 (-3.03) | -1.22 (-1.11) | | -0.4 (-3.37) | -0.125 (-1.11) |
| $H_t$ $U_t$ | 0.0019 (4.41) | 0.0009 (2.35) | | 0.002 (4.68) | 0.0009 (2.31) |
| Ln $S_K$ | 0.25 (4.04) | 0.17 (2.91) | | | |
| Ln $S_H$ | 0.32 (4.67) | 0.34 (5.04) | | | |
| Ln $(n+g+\delta)$ | -1.756 (-8.48) | -1.404 (-6.68) | | | |
| Ln $(U_t/L_t)$ | 0.06 (3.19) | 0.055 (3.04) | | 0.048 (2.47) | 0.046 (2.52) |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | | | 0.33 (5.39) | 0.22 (3.74) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | | | 0.4 (5.66) | 0.4 (5.91) |
| | | | $\alpha =$ | .19 (5.33) | .136 (3.99) |
| | | | $\beta =$ | .23 (4.74) | .24 (6.44) |
| | | | $\gamma =$ | .03 (2.66) | .03 (2.63) |
| Adj R-sq | .71 | .72 | | .68 | .71 |
| F Value | 110.221 | 116.945 | | 113.185 | 125.886 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal

Diagnostics on Table X:

*Test of Internal Restriction: F=14.09> $F_{0.001\ level}$ ➔ reject null that restriction holds.

*Test of Restricting Shifter to Zero: F=5.43> $F_{0.05\ level}$ ➔ reject null that shifter is zero.

data on human capital correspond more closely to the rate of accumulation $S_H$ or to the level of human capital h" (pp.14-5). Thus the construction of our MRW augmented model is performed in terms of both the level and share of income devoted to urban capital, to explore the relationships involved from more than one perspective. Equation 4.18 (b) used the level of urban agglomeration while the new specification which uses $S_\mu$ is equation 4.19 (b) as explained before, still assuming the level of technology exogenous.

$$(4.19b)\quad \text{Ln}\,(Y_t/L_t) = \alpha/(1-\alpha-\beta-\gamma)\,\text{Ln}\,S_K + \beta/(1-\alpha-\beta-\gamma)\,\text{Ln}\,S_H + \gamma/(1-\alpha-\beta-\gamma)\,\text{Ln}\,S_\mu - [(\alpha+\beta+\gamma)/(1-\alpha-\beta-\gamma)]\,\text{Ln}\,(n+g+\delta) + \text{Ln}\,A_0 + gt$$

which becomes in restricted form:

$$\begin{aligned}\text{Ln}\,(Y_t/L_t) = {} & \alpha/(1-\alpha-\beta-\gamma)\,[\text{Ln}\,S_K - \text{Ln}\,(n+g+\delta)] \\ & +\beta/(1-\alpha-\beta-\gamma)\,[\text{Ln}\,S_H - \text{Ln}\,(n+g+\delta)] \\ & +\gamma/(1-\alpha-\beta-\gamma)\,[\text{Ln}\,S_\mu - \text{Ln}\,(n+g+\delta)] + \text{Ln}\,A_0 + gt\end{aligned}$$

Of course the new construction implies three restrictions whereas when the level of urban agglomeration was used, only two restrictions were imposed. Then the coefficient of urban agglomeration remained the same before and after the restrictions, and the output elasticity with respect to urban capital $\gamma$ didn't affect the coefficients of population, saving, and education, whereas now it does. Furthermore, the growth rate of technology g is no longer affected by the output elasticities with respect to the inputs.

Again the results of Table XI above indicate that the coefficients of the MRW variables display the signs and generally estimates of the output elasticities with respect to the inputs similar to the previous results. The changed specification resulting from the use of the share of income devoted to urban capital as opposed to the level of urban capital has brought with it a tremendous increase in the output elasticity with respect to urban capital $\gamma$.

Table XI: Estimation of Equation 4.19 (b):

Dependent Variable: log of Real GDP per Capita
63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | Restricted |
|---|---|---|
| Constant | 12.92 (33.11) | 11.55 (37.43) |
| t | 0.036 (2.45) | 0.041 (2.68) |
| Ln $S_K$ | 0.32 (6.27) | |
| Ln $S_H$ | 0.43 (7.42) | |
| Ln (n+g+$\delta$) | - 2.32 (-13.77) | |
| Ln $S_\mu$ | 0.48 (12.29) | |
| Ln $S_K$ – Ln (n+g+$\delta$) | | 0.424 (8.7) |
| Ln $S_H$ – Ln (n+g+$\delta$) | | 0.51 (8.89) |
| Ln $S_\mu$ – Ln (n+g+$\delta$) | | 0.52 (13.14) |
| | | $\alpha$ = 0.17 (4.64) |
| | | $\beta$ = 0.21 (5.75) |
| | | $\gamma$ = 0.21 (8.67) |
| Adj R-sq | 0.74 | 0.73 |
| F Value | 212.794 | 239.981 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

*Test of Internal Restriction: F=4.076> $F_{0.05\ level}$ ➔ reject null that restriction holds.

So far however, the estimation supports the inclusion of urban capital into the model even though more rigorous statistical tests and comparisons with other specifications are in order before any conclusion can be reached. We can say however that so far the canvas of interrelationships established in the literature do not get overturned as a result of the inclusion of urban variables in the framework of MRW. This is consistent with other papers testing the influence of other variables like democracy or natural resource endowment within the framework of the same model as explained elsewhere.

*Urban Agglomerations Equation 4.19( c):*

Now adding the same shifter to equation 4.19 (b) that we added to equation 4.18 (b), we get :

$$(4.19c)\ \ln (Y_t/L_t) = \alpha/(1-\alpha-\beta-\gamma) \text{ Ln } S_K + \beta/(1-\alpha-\beta-\gamma) \text{ Ln } S_H + \gamma/(1-\alpha-\beta-\gamma) \text{ Ln } S_\mu - [(\alpha+\beta+\gamma) / ( 1-\alpha-\beta-\gamma)] \text{ Ln } (n+g+\delta) + \text{Ln } A_0 + gt + c_1 \ln H_t + c_2 \ln U_t + c_3 H_t U_t$$

which is the same as equation 4.19(b) above except that technology has been expressed as a function of the intangible inputs human and urban capital. In restricted form, 4.19 ( c) becomes

$$\ln (Y_t/L_t) = \alpha/(1-\alpha-\beta-\gamma) (\text{Ln } S_K - \text{Ln } (n+g+\delta)) + \beta/(1-\alpha-\beta-\gamma) (\text{Ln } S_H - \text{Ln } (n+g+\delta)) + \gamma/(1-\alpha-\beta-\gamma) (\text{Ln } S_\mu - \text{Ln } (n+g+\delta)) + \text{Ln } A_0 + gt + c_1 \ln H_t + c_2 \ln U_t + c_3 H_t U_t$$

Here we have three restrictions also, but the interpretation of the coefficients of the shifter is straight forward. Table XII is the last pedagogical exploration of the first impact of including urban variables into the MRW. More involved statistical analysis will follow.

In the meantime we again see a decrease in the output elasticity with respect to physical capital resulting from the inclusion of the shifter. This fosters the suspicion that the omission of human and urban measures may have been what led to a high $\alpha$ to begin with. However it would premature to make that assertion on the basis of the new results alone. In fact, the output elasticity with respect to urban capital is too high and with respect to physical capital is too low. This changes when we introduce fixed effects later.

The MRW variables are still highly significant and of the expected magnitude, although the decrease in the coefficient of the output elasticity with respect to human capital is as manifest as the increase in the output elasticity with respect to urban capital.

The analysis proceeds with a re-estimation of all the equations 4.18 (b) through 4.19 ( c) with fixed and random effects followed by a battery of statistical tests.

On the following pages, Tables XII, XIII, XIV, XV, and XVII contain a summary of all the results.

## Table XII: Estimation of Equation 4.19 (c):

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | | Restricted | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Constant | 12.97 (29.42) | 12.34 (33.83) | 12.28 (32.3) | 11.97 (41.82) |
| t | 0.02 (1.46) | 0.003 (0.209) | 0.021 (1.51) | 0.002 (0.17) |
| Ln $H_{1t}$ | -0.006 (-0.09) | | 0.0056 (0.08) | |
| Ln $H_2$ | | .207 (4.11) | | 0.22 (4.77) |
| Ln $U_t$ | -0.82 (-8.03) | -0.61 (-6.07) | -0.88 (-8.64) | -0.627 (-6.3) |
| $H_t$ $U_t$ | 0.001 (3.61) | 0.0004 (1.10) | 0.001 (3.75) | 0.0004 (1.06) |
| Ln $S_K$ | 0.16 ( 3.13) | 0.09 (1.87) | | |
| Ln $S_H$ | 0.23 (4.08) | 0.28 (4.98) | | |
| Ln $(n+g+\delta)$ | -1.63 (-9.44) | -1.34 (-7.67) | | |
| Ln $S_\mu$ | 0.66 (12.96) | 0.65 (12.84) | | |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | | .2 (3.89) | .11 (2.22) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | | .26 (4.48) | .29 (5.3) |
| Ln $S_\mu$ – Ln $(n+g+\delta)$ | | | .7 (13.79) | .67 (13.43) |
| | | | $\alpha$ = .09 (3.32) | .05 (1.92) |
| | | | $\beta$ = .12 (3.02) | .136 (4.61) |
| | | | $\gamma$ = .32 (4.99) | .32 (10.98) |
| Adj R-sq | .79 | .81 | .79 | .81 |
| F Value | 177.55 | 187.364 | 197.215 | 212.613 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

Diagnostics on Table XII:

*Test of Internal Restriction: F=8.88 > $F_{0.01 level}$ ➔ reject null that restriction holds.

*Test of Restricting Shifter to Zero: F=45> $F_{0.05 level}$ ➔ reject null that shifter is zero.

*Equations 4.18(b), 4.18 ( c) , 4.19 (b), and 4.19 ( c ) in Models of Fixed and Random Effects:*

Table XIII: Estimation of Equation 4.18 (b) with Fixed and Random Effects:

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | | Restricted | |
|---|---|---|---|---|
| | (1)FEM | (2)REM | (3)FEM | (4)REM |
| Constant | fixed effects | 9.67 (24.96) | fixed effects | 9.41 (34.21) |
| t | 0.13 (14.02) | 0.11 (14.5) | 0.126 (14.31) | 0.11 (14.94) |
| Ln $S_K$ | 0.234 (6.1) | 0.27 (7.25) | | |
| Ln $S_H$ | 0.11 (2.62) | 0.136 (3.23) | | |
| Ln $(n+g+\delta)$ | -0.33 (-1.84) | -0.58 (-3.39) | | |
| Ln $(U_t /L_t)$ | 0.13 (2.15) | 0.063 (1.37) | 0.13 (2.15) | 0.064 (1.38) |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | | 0.23 (6.19) | 0.28 (7.6) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | | 0.11 (2.68) | 0.14 (3.5) |
| | | | $\alpha$ = .17 (9.6) | .19 |
| | | | $\beta$ = .08 (3.74) | .1 |
| | | | $\gamma$ = .1 (2.54) | .043 |
| Adj R-sq | 0.99 | 0.62 | 0.99 | 0.62 |
| F Value | 327.48 | | 253.63 | |
| Hausman Test | | 28.58 | | 26.16 |
| (p-value) | | 0.0000 | | 0.0000 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

Diagnostics on Table XIII:

*Test of Internal Restriction:F~0> $F_{0.001 level}$ ➔ fail to reject null that restrictions hold.

*FE vs. OLS: (Another F-test) F=46.2> $F_{0.001\ level}$ ➔reject null that fixed effects are zero.

*FE. vs. RE: LM=1.42 vague result to reject the null. Hausman test favors FE.

In Table XIII, fixed effects and random effects models are tested for equation 4.18b where no shifter is assumed and the level of urban capital per capita rather than the share of income going to urban capital is used. Note that the coefficients of $\gamma$ and $\beta$ are significant.

Table XIV: Estimation of Equation 4.19 (b) with Fixed and Random Effects:

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | | Restricted | |
|---|---|---|---|---|
| | (1) FEM | (2) REM | (3) FEM | (4) REM |
| Constant | fixed effects | 9.32 (22.15) | fixed effects | 9.142 (31.37) |
| t | 0.11 (15.77) | 0.1 (13.76) | 0.11 (14.7) | 0.1 (13.87) |
| Ln $S_K$ | 0.23 (5.95) | 0.26 (6.92) | | |
| Ln $S_H$ | 0.11 (2.6) | 0.128 (3.02) | | |
| Ln $(n+g+\delta)$ | -0.36 (-1.99) | -0.63 (-3.63) | | |
| Ln $S_\mu$ | 0.016 (0.41) | 0.127 (2.18) | | |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | | 0.23 (6.03) | 0.26 (7.12) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | | 0.11 (2.7) | 0.13 (3.22) |
| Ln $S_\mu$ – Ln $(n+g+\delta)$ | | | 0.055 (0.08) | 0.13 (2.37) |
| | | | $\alpha$ = 0.17(2.11) | 0.18 |
| | | | $\beta$ = 0.083 (2.94) | 0.09 |
| | | | $\gamma$ = 0.0037 (0.01) | 0.032 |
| Adj R-sq | 0.99 | 0.62 | 0.99 | 0.62 |
| F Value | 160.9 | | 197.88 | |
| Hausman Test | | 32.9 | | 31.39 |
| (p-value) | | 0.0000 | | 0.0000 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

Diagnostics on Table XIV:

*Test of Internal Restriction:F~0> $F_{0.001 level}$ → fail to reject null that restrictions hold.

*FE vs. OLS: (Another F-test) F=37.3> $F_{0.001 level}$ →reject null that fixed effects are zero.

*FE. vs. RE: LM=0.9 fail to reject the null that variance of errors is zero. Favor FE.

In Table XIV, fixed effects and random effects models are tested for equation 4.19b where no shifter is assumed and the share of income going to urban capital rather than the level of urban capital per capita is used. Note that the coefficient of $\gamma$ is insignificant, whereas that of $\beta$ is significant.

Table XV: Estimation of Equation 4.18 (c) with Fixed Effects:

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | | Restricted | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Constant | fixed effects | fixed effects | fixed effects | fixed effects |
| t | 0.12 (9.65) | 0.11 (8.13) | 0.11 (9.52) | 0.108 (8.12) |
| Ln $H_t$ | -0.16 (-2.77) | | -0.133 (-2.43) | |
| Ln $H_2$ | | -0.043 (-0.9) | | -0.031 (-0.67) |
| Ln $U_t$ | -0.39 (-2.48) | -0.4 (-2.4) | -0.35 (-2.23) | - 0.36 (-2.24) |
| $H_t U_t$ | 0.002 (4.51) | 0.0018 (3.77) | 0.002 (4.27) | 0.0017 (3.65) |
| Ln $S_K$ | 0.24 (6.09) | 0.22 (5.36) | | |
| Ln $S_H$ | 0.12 (2.8) | 0.14 (3.18) | | |
| Ln $(n+g+\delta)$ | -0.05 (-0.28) | -0.17 (-0.86) | | |
| Ln $(U_t/L_t)$ | 0.15 (2.28) | 0.19 (2.87) | 0.15 (2.24) | 0.18 (2.8) |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | | 0.23 (5.89) | 0.21 (5.28) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | | 0.106 (2.54) | 0.13 (3.04) |
| | | | $\alpha$ = .17 (5.32) | .15 (8.3) |
| | | | $\beta$ =.08 (2.47) | .085 (4.19) |
| | | | $\gamma$ =.1 (1.99) | .14 (3.48) |
| Adj R-sq | .99 | .99 | .99 | .99 |
| F- Value | 121.0225 | 134.94 | 132.28 | 173.95 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

Diagnostics on Table XV:

*Test of Internal Restriction:F~0> $F_{0.001 level}$ → fail to reject null that restrictions hold.

*FE vs. OLS: (Another F-test) F=45> $F_{0.001 level}$ →reject null that fixed effects are zero.

*FE. vs. RE: LM=0.88 fail to reject the null that variance of errors is zero. Favor FE.

*Restricting Shifter to Zero: F=9.9> $F_{0.01 level}$ → reject null that shifter is zero.

In Table XV, equation 4.18c where a shifter is assumed, and the level of urban capital per capita is used rather than the share of income going to urban capital, is re-estimated under LSDV. Note that the coefficients of $\gamma$ and $\beta$ are significant.

Table XVII: Estimation of Equation 4.19 (c) with Fixed Effects:

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | | Restricted | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Constant | fixed effects | fixed effects | fixed effects | fixed effects |
| t | .1 (8.85) | 0.09 (7.1) | 0.099 (8.67) | 0.09 (6.87) |
| Ln $H_t$ | -0.196 (-3.51) | | -0.167 (-3.13) | |
| Ln $H_2$ | | -0.048 (-1.0) | | -0.037 (-0.8) |
| Ln $U_t$ | -0.3 (-1.96) | -0.27 (-1.65) | -0.24 (-1.62) | -0.23 (-1.39) |
| $H_t$ $U_t$ | 0.002 (4.54) | 0.0017(3.6) | 0.002 (4.26) | 0.0016 (3.44) |
| Ln $S_K$ | 0.24 (6.07) | 0.21 (5.14) | | |
| Ln $S_H$ | 0.11 (2.6) | 0.14 (3.1) | | |
| Ln $(n+g+\delta)$ | -0.06 (-0.31) | -0.22 (-1.12) | | |
| Ln $S_\mu$ | 0.04 (1.11) | 0.038 (0.92) | | |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | | 0.23 (5.84) | 0.21 (5.07) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | | 0.09 (2.32) | 0.13 (3.01) |
| Ln $S_\mu$ – Ln $(n+g+\delta)$ | | | 0.03 (0.81) | 0.026 (0.4) |
| | | | $\alpha$ = .18 (4.63) | .15 (5.55) |
| | | | $\beta$ = .072 (2.41) | .096 (3.14) |
| | | | $\gamma$ = .022 (0.47) | .02 (.41) |
| Adj R-sq | .99 | .99 | .99 | .99 |
| F Value | 109.72 | 120.5 | 125.58 | 109.72 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

Diagnostics on Table XVII:

*Test of Internal Restriction:F~0.9> $F_{0.001 level}$ → fail to reject null that restrictions hold.

*FE vs. OLS: (Another F-test) F=27.87> $F_{0.01\ level}$ →reject null that fixed effects are zero.

*FE. vs. RE: LM=0.75 fail to reject the null that variance of errors is zero. Favor FE.

*Restricting Shifter to Zero: F=5.82> $F_{0.05\ level}$ → reject null that shifter is zero.

In Table XVI, equation 4.19c where a shifter is assumed, and the share of income going to urban capital is used rather than the level of urban capital per capita, is re-estimated under LSDV. Note that the coefficient of $\gamma$ is insignificant, whereas that of $\beta$ is significant.

*Results of Statistical Tests on All Regressions of Equations 4.18 &4.19:*

1 - In every case the internal restrictions on the coefficients of equations 18 and 19 fail to hold unless fixed or random effects are used. This means for example that tests of the restrictions that coefficients are equal in magnitude and opposite in sign come back with the result that we can reject the null that the restrictions hold with high degrees of significance like 0.001. When fixed and random effects models are estimated for the same equations, we fail to reject the null that the restrictions hold. Because the theory implies that the restrictions are valid, this result favors GLS and LSDV over OLS.

2 - For each of the four equations in question, an F-test yields the result that we can safely reject the null that country effects are equal to zero. Thus LSDV is favored over OLS in each case with an F-statistic equal to 48, 45, 37.3, and 27.87 respectively for 4.18(b) through 4.19( c). Similar results are obtained if the unrestricted versions of equations 4.18(b) through 4.19( c) are compared.

3- In all the cases, the Hausman test rejects the null that country effects are uncorrelated with the included variables. This suggests fixed rather than random effects are in order.

4 - In three cases out of four, an LM statistic suggests that LSDV is favored over GLS, and we fail to reject the null that the variance of the errors is equivalent to zero. This was the case for equations 4.18 ( c), 4.19(b), and 4.19 (c ) with LM statistics equal to 0.9, 0.88, and 0.75 respectively. In the case of equation 4.18 (b), the LM statistic was equal to 1.42 which suggests that we can reject the null

only at the 0.25 level of significance. So the evidence there is present but not overwhelming in favor of fixed effects. Given the results of the Hausman test in Tables XIII and XIV, and in the appendix however, the evidence favors the fixed effects models in all cases.

5- Comparing 4.18(b) to 4.18 (c ) and 4.19 (b) to 4.19 ( c), i.e., testing for whether including the shifter is valid by testing the restrictions that the joint coefficients of the three variables in the shifter are zero, we reject the null that the shifter variables are simultaneously equal to zero with an F-statistic of 9.9 for equations 4.18, and an F of 10 for equations 4.19. Thus the statistical evidence favors having a shifter.

6 - When we do a joint test of whether the proxies for urban and the variables in the shifter belong in MRW's equation, the results come out positive for both of 4.18 ( c) and 4.19 ( c). For the latter, F=5.82 and 7.7 depending on whether average years of education are deflated or not respectively, i.e., depending on whether Ln $H_t$ or Ln $H_2$ are included. For the equation 18( c), F= 7.34 and 9.02 respectively depending on whether years of education were deflated or not.

7- Upon examining the coefficients of the urban input in equations 18 and 19, we are struck by the fact that the output elasticity with respect to urban capital $\gamma$ is insignificant in both of equations 19 b & c where $S_\mu$ is used, but significant when U/L is used as in equations 18 b & c. This result is robust to changing the specification of the shifter, for example when the three shifter variables H, U, and HU are not in logarithmic form. The signs of these shifters also remain the same, and $S_\mu$ stays insignificant. When the proxy for U is changed from urban population in agglomerations to total population in agglomerations, $S_{\mu}$ stays insignificant as well. On the other hand, when U/L is redefined so it reflects the change in the proxy U from urban population in agglomerations to total population in agglomerations, it stays significant and of the same sign, even though the magnitude changes (see Table XXVI in Appendix).

Based on all that preceded, we will concentrate on equations 18 (b) and 18 (c ) under LSDV. That does not mean the other equations have nothing to contribute still, but only that the estimates presented in Tables XV and in Table XIII seem to be the most statistically reliable.

Under the restricted versions of these equations, that is columns (3) and (4) in both tables, the estimates of the output elasticity with respect to physical capital range between .15 and .18. The output elasticity with respect to human capital ranges between .07 and .1, while the output elasticity with respect to urban capital is between .1 and .14 for equation 4.18 ( c) and around .02 for equation 4.19 ( c ) where the share of income to urbanization is used. The problem here is that in the second case the output elasticity with respect to urban capital $\gamma$ was statistically insignificant.

Thus, to answer the question posed earlier by MRW about whether human capital should enter as share of income going to human capital or level of human capital, an insignificant coefficient for the share of income going to urban capital may suggest that the share of income going to urban capital $S_{\mu}$ in equations 4.19 is inappropriate. The measure of urban capital in economic growth models 4.18 however, Ln U/L gives a significant output elasticity with respect to urban capital. Alternatively, the equation using pooled data without country effects finds a significant coefficient for Ln $S_\mu$ and the output elasticity with respect to urban capital. High correlation between $S_\mu$ and the country effects may prevent a precise estimate of the coefficient of $S_\mu$. in which urban capital should be included in economic growth models is 18 ( c) with the level of urban agglomeration, not the share of income going to urban capital as in 19 ( c). This conclusion is reinforced also by another insignificant coefficient for the share of income going to urban capital in 19 (b), without the shifter.

Hence from this point on, and after taking all the statistical and theoretical considerations into account, the results discussed will be for equations 4.18 (c ) and 4.18 (b) (with and without the shifter) under fixed effects for the restricted versions. One thing about these two specifications is how strikingly similar their estimates for the implied $\alpha$, $\beta$, and $\gamma$ are: In both cases they are exactly 0.17, 0.08, and 0.1 respectively. However, in the case without a shifter, i.e., 18 (c), the coefficient of the growth rate of population becomes insignificant when the unrestricted version is used. This result is unsettling even though it is mitigated by the fact that the coefficients on the restricted version of 18 (c) are all significant, and as mentioned before a test of the internal restriction shows that it does hold with a high degree of significance (0.01).

Upon examining the coefficients of the restricted version of 18 (c ), column (3), however, we notice that the coefficient of the average years of education for population over 25 is negative or insignificant as in column (4). This is consistent with the results obtained in the literature showing systematically no or negative correlation between proxies for education and real income per capita. Also, all the previous tests have shown that Ln $U_t$ is also negative and significant.

It is premature however to conclude that increases in the levels of urbanization and schooling would shift the level of income per capita down. To draw that conclusion, we have to first take and evaluate partial derivatives with respect to $H_t$ and $U_t$. For example, looking at column (3) of equation 18 ( c), Table XV, the partial of income per capita with respect to $H_t$ is:

$$\partial \text{ Ln } (Y_t/L_t)/\partial H_t = - 0.133 / H_t + 0.002 U_t$$

and the partial of income per capita with respect to $U_t$ is:

$$\partial \text{ Ln } (Y_t/L_t)/\partial U_t = - 0.35 / U_t + 0.002 H_t$$

Thus given that the means of $H_t$ and $U_t$ in the sample are respectively 4.38 years and 43.79 percent (of urban population living in large urban agglomerations), the values of the partials above at the means become:

$$\partial \text{ Ln } (Y_t/L_t)/\partial H_t = - 0.0304 + 0.0876 = 0.05$$

which means that an increase of one in the level of years of education *increases* per capita income by 0.057 percent. However, this result obtains more forcefully the higher the combined levels of $H_t$ and $U_t$, which is the Rauch effect.

Similarly, the partial of per capita income with respect to $U_t$ becomes at the means:

$$\partial \text{ Ln } (Y_t/L_t)/\partial U_t = - 0.008 + 0.009 = 0.001$$

which means that an increase of one percent in the proportion of urban population living in large urban agglomerations *increases* per capita income by 0.001 %, which might be economically negligible, but still positive and significant. And again this result obtains more forcefully, and per capita income increases faster with $U_t$, the higher the level of education, $H_t$ .

As both education and urbanization, $H_t$ and $U_t$, increase together, both $\partial Ln(Y_t/L_t)/\partial H_t$ and $\partial Ln(Y/L)/\partial U_t$ above increase since theoretically the negative component in the partials asymptotically approaches zero as $H_t$ and $U_t$ increase to infinity. This implies that an increase in the geographic concentration of human capital, represented by a simultaneous increase in $H_t$ and $U_t$, plays out the role that Rauch prescribed, affecting income positively.

On the other hand if we take partial derivatives with respect to Ln H and Ln $U_t$ instead of just H and U, the results become:

$$\partial \text{ Ln } (Y_t/L_t)/\partial \text{ Ln } H_t = -0.133 + 0.002 \, H_t \, U_t$$

At the point of means this becomes equal to -0.133 + 0.002 (4.38)(43.79) = 0.25 which implies that a ten-percent increase in the average years of education of population over 25, increases the standard of living by 2.5 %, a significant positive result.

And similarly , $\partial \text{ Ln } (Y_t/L_t)/\partial \text{ Ln } U_t = -0.35 + 0.002 \, H_t \, U_t \rightarrow$

$$= -0.35 + 0.002 \, (4.38) \, (43.79)$$

= 0.034 at the point of means.

This result implies that a ten-percent increase in the proportion of urban population living in large agglomerations increases income per capita by a third of one percentage point, not a large, but still a positive increase. Furthermore, these results reinforce the conclusions obtained from taking the partials with respect to $H_t$ and $U_t$ above. The negative signs on the coefficients can be misleading outside the proper context for interpretation as in regression 4.18 ( c).

The key to understanding this relationship is the *Rauch effect* explained before. The negative signs for $H_t$ and $U_t$ hold except for the countervailing effect of the other variable in the interaction term HU. To see the power of this relationship, pretend H is zero when taking $\partial$ Ln $(Y_t/L_t)/\partial U_t$, or that $U_t$ is zero when taking $\partial$ Ln $(Y_t/L_t)/\partial H_t$, and the negative result will obtain, as typically found in the literature albeit the coefficient will asymptotically approach zero as the denominator increases.

Thus the most important new findings in the regressions above are:

1) Human capital is significant in all specifications, and the value of $\beta$ converged to a range between 0.072 and 0.083 in all equations 4.18 and 4.19 with or without the shifter under fixed effects. This supports the inclusion of human capital as MRW (1990) suggest.

2) Urban capital is significant when equations 4.18 are estimated. There $\gamma$ is 0.1 with or without the shifter. For equations 4.19, urban capital is significant only under OLS or REM, where FEM are warranted. This suggests that the urban measure in 4.19 may be correlated with the

country effects, which leads to imprecise estimates. Nevertheless, evidence is present that the inclusion of urban capital in the growth function is justified.

3) Physical capital is significant in all specifications. $\alpha$ converged to a range between 0.17 and 0.18 in all regressions 4.18 and 4.19 with or without the shifter under fixed effects. The decrease in the value of the output elasticity with respect to physical capital compared to other models is evident. Perhaps some of the rents accruing to owners of urban capital was previously attributed to $\alpha$.

4) On the other hand, the specification of the shifter as a function of both human and urban capital also finds support in this study. This confirms the role of intangible inputs as possible enhancers of productivity as Islam (1995) suggests. Moreover, the introduction of an interaction term between human and urban capital in the shifter reconciles the previous findings of a negative correlation between measures of human capital and per capita income, with the reasonable presumption that human capital should affect income positively.

5) Deflating human capital by the pupil-teacher ratio in primary school to account for the quality of human capital, yields insignificant results. If this procedure correctly accounts for quality of education, then the insignificance of the deflated variable implies that confusing quality and quantity of education is not the reason human capital measures

conventionally exhibit negative or no correlation with per capita income. Point four above suggests that the way human capital is modeled in the shifter is more important.

6) Fixed effects models prove to be preferred to OLS and random effects specifications under different statistical tests. Since fixed effects imply that each country has a different intercept term which contains that fraction in income per capita that is unexplained by the independent variables in the model, the results support the conclusion that institutions, culture, technology, resources, and whatever else goes into the intercept are more important than is generally acknowledged.

7) Making policy to promote a higher standard of living on the basis of the results above suggests that those policies which increase the stocks of human and urban capital or which raise the intercept term of the country in question, are also the ones that promote development. Increasing human capital is expensive but relates basically to increasing the average years of education of the populace. On the other hand, increasing urban capital relates to undertaking infrastructure projects that yield those public and business services with the highest marginal value product. This means that wasteful massive construction projects in the wrong place are not a contribution to building urban capital since a crucial component in the definition of urban capital is location. As for policies that improve the country effects, these pertain to institutions and culture as well as technology

and preferences among other things. Tackling those factors might be beyond the scope of this study.

# CHAPTER VII

## THREE IMPLICATIONS

In the concluding chapter of this study, the model developed and estimated in the previous chapters will be extended into three different directions or implications: the first has to do with the issue of convergence, the second relates to the simultaneous explanation of urban agglomeration and economic growth, and the third pertains to the implications of ranking countries on the basis of their estimated fixed effects.

### *Implication One: The Issue of Convergence*

All the models tested hitherto have assumed that countries are in their steady states. Indeed Mankiw, Romer, and Weil (1990), henceforth MRW, made a point of making that assumption then showing that their model is capable of explaining inter-country differences in per capita income *under that assumption.* However, they then estimate their models assuming that countries are not in their steady state, which basically involves recalculating the regression coefficients after adding a lagged value of the dependent variable to the independent variables. In addition to the parameters considered so far, this approach estimates the rate of convergence to the steady state $\lambda$. MRW found that $\lambda$ increased from 0.006 to 0.0142 after the inclusion of human capital. In other words the gap between the actual value and the steady state closed by 0.0142 percent per year rather than 0.006 percent per year. These convergence rates are quite low suggesting that it takes 166 or 70 years to reach the steady state depending on whether the convergence rate is 0.006 or 0.0142.

Then Islam (1995) introduces individual country effects and finds faster rates of convergence than MRW estimated without including human capital. In fact the most important empirical finding among Islam's results is a faster rate of convergence $\lambda$ (since his estimated output elasticity with respect to capital $\alpha$ was relatively high at 0.43 as pointed out before). Nevertheless Islam's estimates of $\lambda$ of 0.0375, 0.044 and 0.0913 for his large, intermediate and OECD samples are larger than MRW's estimates. However, Islam adds : "There is probably little solace to be derived from finding that countries in the world are converging at a faster rate, when the points to which they are converging remain very different" (p.1162).

And even though this dissertation is not directly concerned with the question of convergence, but with explaining cross-country differences in the levels of income, another test of the robustness of our results is how they would change if we assumed that countries are not in their steady states. Does our addition of urbanization and a shifter imply a higher or a slower rate of convergence between countries?

Thus assuming a partial adjustment operator $\lambda$ that determines the rate at which actual per capita income converges to the steady state, the rate of change of income per capita over time is determined by the following function:

(7.1) $d\, Ln\, (Y_t / L_t) / d\, t = \lambda\, [Ln\, (Y/L)^* - Ln\, (Y_t / L_t)\, ]$, which implies that the change of per capita income $(Y_t / L_t)$ is a function of deviation from the steady state $(Y/L)^*$.

This means that the level of per capita income in period two, $t_2$ , is a function of the level of income in period one, $t_1$ , the steady state, and the rate of convergence $\lambda$ according to the following specification:

(7.2) $Ln\, (Y_t / L_t)_{two} = (\, 1 - e^{-\lambda t}\, )\, Ln\, (Y/L)^* + e^{-\lambda t}\, Ln\, (Y_t / L_t)_{one}$

If we assume that the equations 4.18 (b), 4.18 ( c ), 4.19 (b), and 4.19 ( c), determine the steady state of income, then we can substitute any of them into $Ln\, (Y/L)^*$ above to end up with a model of economic growth that does not assume a steady state.

Since empirical considerations favored equations 4.18 (b) and 4.18 ( c) under LSDV, we check how these two specifications fare under the new assumption of no steady state.

Thus substituting 4.18( b ) from before into the term $Ln\, (Y/L)^*$, we get

$$(7.3)\quad Ln\, (Y_t / L_t)_{two} = (\, 1 - e^{-\lambda t})\{(\alpha/1-\alpha-\beta)\, Ln\, S_K + (\beta/1-\alpha-\beta)\, Ln\, S_H - [(\alpha+\beta) / (\, 1-\alpha-\beta)]\, Ln\, (n+g+\delta) + \gamma/(1-\alpha-\beta)\, Ln\, (U_t / L_t) + (1-\alpha-\beta+\gamma)/\gamma\, Ln\, A_0 + (1-\alpha-\beta+\gamma)/\gamma\, gt\} + e^{-\lambda t}\, Ln\, (Y_t / L_t)_{one}$$

which can be rewritten as:

$$(7.3a)\ Ln\,(Y_t/L_t)_{two} = (1 - e^{-\lambda t})(\alpha/1-\alpha-\beta)\,Ln\,S_K + (1 - e^{-\lambda t})(\beta/1-\alpha-\beta)\,Ln\,S_H$$
$$- [(1 - e^{-\lambda t})(\alpha+\beta) / (1-\alpha-\beta)]\,Ln\,(n+g+\delta) + (1 - e^{-\lambda t})\gamma/(1-\alpha-\beta)\,Ln\,(U_t/L_t)$$
$$+ (1 - e^{-\lambda t})(1-\alpha-\beta+\gamma)/\gamma\ Ln\,A_0 + (1 - e^{-\lambda t})(1-\alpha-\beta+\gamma)/\gamma\,gt + e^{-\lambda t}\,Ln\,(Y_t/L_t)_{one}$$

which becomes in restricted form:

$$(7.3b)\ Ln\,(Y_t/L_t)_{two} = (1 - e^{-\lambda t})(\alpha/1-\alpha-\beta)\,[Ln\,S_K - Ln\,(n+g+\delta)]$$
$$+ (1 - e^{-\lambda t})(\beta/1-\alpha-\beta)\,[Ln\,S_H - Ln\,(n+g+\delta)]$$
$$+ (1 - e^{-\lambda t})\gamma/(1-\alpha-\beta)\,Ln\,(U_t/L_t)$$
$$+ (1 - e^{-\lambda t})(1-\alpha-\beta+\gamma)/\gamma\ Ln\,A_0 + (1 - e^{-\lambda t})(1-\alpha-\beta+\gamma)/\gamma\,gt$$
$$+ e^{-\lambda t}\,Ln\,(Y_t/L_t)_{one}$$

Or if $lnA_t = lnA_0 + gt + c_1\ lnH_t + c_2\,lnU_t + c_3\,H_t\,U_t$, ➔

$$(7.4)\ Ln\,(Y_t/L_t)_{two} = (1 - e^{-\lambda t})(\alpha/1-\alpha-\beta)\,Ln\,S_K + (1 - e^{-\lambda t})(\beta/1-\alpha-\beta)\,Ln\,S_H$$
$$- [(1 - e^{-\lambda t})(\alpha+\beta) / (1-\alpha-\beta)]\,Ln\,(n+g+\delta) + (1 - e^{-\lambda t})\gamma/(1-\alpha-\beta)\,Ln\,(U_t/L_t)$$
$$+ (1 - e^{-\lambda t})(1-\alpha-\beta+\gamma)/\gamma\ Ln\,A_0 + (1 - e^{-\lambda t})(1-\alpha-\beta+\gamma)/\gamma\,gt + (1 - e^{-\lambda t})\,(1-\alpha-\beta+\gamma)/\gamma$$
$$c_1\,Ln\,H_t + (1 - e^{-\lambda t})(1-\alpha-\beta+\gamma)/\gamma\,c_2\,ln\,U_t + (1 - e^{-\lambda t})\,(1-\alpha-\beta+\gamma)/\gamma\,c_3\,H_t\,U_t$$
$$+ e^{-\lambda t}\,Ln\,(Y_t/L_t)_{one}$$

which becomes in restricted form:

$$(7.4a)\ Ln\,(Y_t/L_t)_{two} = (1 - e^{-\lambda t})(\alpha/1-\alpha-\beta)\,[Ln\,S_K - Ln\,(n+g+\delta)]$$
$$+ (1 - e^{-\lambda t})(\beta/1-\alpha-\beta)\,[Ln\,S_H - Ln\,(n+g+\delta)]$$
$$+ (1 - e^{-\lambda t})\gamma/(1-\alpha-\beta)\,Ln\,(U_t/L_t)$$
$$+ (1 - e^{-\lambda t})(1-\alpha-\beta+\gamma)/\gamma\ Ln\,A_0 + (1 - e^{-\lambda t})(1-\alpha-\beta+\gamma)/\gamma\,gt$$
$$+ (1 - e^{-\lambda t})\,(1-\alpha-\beta+\gamma)/\gamma\,c_1\,Ln\,H_t + (1 - e^{-\lambda t})(1-\alpha-\beta+\gamma)/\gamma\,c_2\,ln\,U_t$$
$$+ (1 - e^{-\lambda t})\,(1-\alpha-\beta+\gamma)/\gamma\,c_3\,H_t\,U_t + e^{-\lambda t}\,Ln\,(Y_t/L_t)_{one}$$

Estimating the equations above in restricted form using LSDV, we obtain the results presented in the following table:

Table XIX: Estimation of Equations 4.18 with Fixed Effects with Lagged Y:

Dependent Variable: log of Real GDP per Capita in Period Two

63 countries at 6 five-year intervals (1965-85)

| | Restricted | |
|---|---|---|
| | (1)No Shifter | (2)W/shifter |
| Constant | fixed effects | fixed effects |
| t | 0.12 (13.27) | 0.104 (8.73) |
| Ln $(Y_t/L_t)_{one}$ | 0.076 (4.58) | 0.063 (3.65) |
| Ln $H_t$ | | -0.105 (-1.9) |
| Ln $U_t$ | | -0.21 (-1.29) |
| $H_t U_t$ | | 0.0016 (3.64) |
| Ln $(U_t/L_t)$ | 0.088 (1.47) | 0.1 (1.53) |
| Ln $S_K$ – Ln $(n+g+\delta)$ | 0.234 (6.35) | |
| Ln $S_H$ – Ln $(n+g+\delta)$ | 0.12 (2.91) | |
| Implied $\alpha$ = | . 18 (6.65) | .17 (6.76) |
| Implied $\beta$ = | .09 (3.12) | .09 (2.99) |
| Implied $\gamma$ = | .07 (1.47) | .08 (1.53) |
| **Implied $\lambda$ =** | **.104** (3.25) | **.11** (3.98) |
| Adj R-sq | .99 | .99 |
| F- Value | 56.03 | 40.76 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal

First a test of whether the shifter should be jointly constrained to zero yields a rejection of that null at an $F=7.35 > F_{3,287}$ ~0.01 level of significance. In Table XIX above, the implied values of $\alpha$= .18 and .17, and the implied values of $\beta$ = .09 are remarkably similar to each other, and to the implied values of $\alpha$ and $\beta$ when the steady state is assumed for the equations above. As for the estimated value of $\gamma$, it declines a little under the assumption of disequilibrium to .07 and .08 from .1 before when the steady state was assumed. Furthermore, the coefficients of Ln $(U_t / L_t)$ and of $\gamma$ are only significant at the ten-percent level using a one-tailed test. The lagged dependent variable has taken away some of the explanatory power of the urban variable whether input or shifter, but not enough to do away with its impact all together. We will see in the next section that these results are improved much when the same equations is re-estimated with LSDV and 2SLS, where the second equation explains Ln U/L.

Most importantly though, our implied estimate for the coefficient of convergence $\lambda$ is higher than the estimates of MRW and of Nazrul Islam. In fact our estimate of $\lambda$= .104 and .11 respectively is higher than the one Islam obtains even for his small OECD sample, .0913. In his somewhat equivalent intermediate sample, $\lambda$ = .044. Ours is more than two times that value, which implies that convergence takes place that much faster with the inclusion of human and urban capital, and even faster if a shifter is added.

Moreover, Nazrul Islam obtains extremely large values of $\alpha$ and negative or insignificant values for $\beta$ in conjunction with his estimate of $\lambda$. The table above shows that this need not be case if a time variable is included, and human capital is measured differently. As for as the rates of convergence estimated here, they imply that under our model, countries can bridge the gap between their actual and steady state per capita income completely in 9 to 10 years.

*Implication Two: Explaining the Urban Enigma*

Given the evidence in favor of the inclusion of urban capital in the Solow model, first I try to explain the measures used as urban inputs in 4.18 (b) and 4.19 (b). Recall that of these the first was Ln $(U_t / L_t)$ and the second was Ln $S_\mu$. Hence we begin with the question of whether urban agglomerations and urban agglomerations per urban population are determined by the same factors that determine different measures of urban concentration in general.

Typically, urban concentration is either a) the urban percentage, represented by the share of population living in urban areas, b) metropolitan percentage, represented by the proportion of the urban population living in cities above a certain cutoff point typically 250 thousand, or c) different primacy indices, which range from the percentage of the urban or total population living in the largest city as in Moomaw and Shatter (1996) to the population of the largest city as in Ades and Glaeser (1995) to the ratio of the largest to the second largest city as in Alwosabi (1996).

Then there is the Herfindahl of urban concentration developed by Wheaton and Shishido (1981) which weighs urban concentration by the distribution of the population among differently sized urban areas.

However, the measure of urban agglomeration used in the this study has not been the subject of extensive research in the urban economics literature because it is a unique blend of measures of metropolitan concentration and urban primacy. The variable $S_{\mu}$ for example is equal to the percentage of *total* population living in urban agglomerations of 750 thousand and above in 1990. For 35 out of 63 countries in our sample there is only one agglomeration of that size. For a few more there is only two or three agglomerations of that size. And only a handful of countries in the world have plenty of them, like the United States and India.

With an index of urban agglomeration like $(U_t/L_t)$, measured as the proportion of urban population in urban agglomerations divided by total population, can traditional factors that are usually used to explain different measures of urban concentration be used to explain $(U_t/L_t)$ as well?

Wheaton and Shishido (1981), henceforth WS, have one of the best discussions on the variables that affect urban concentration, and in what follows, I borrow freely from the theoretical section in their paper.

WS argue that cities are the result of the interaction of two opposing forces one to take advantage of economies of scale (and agglomeration economies of course) and the other to lower transportation cost. The state of balance between these two opposing forces generates the function for the optimum size for each urban concentration, depending on the abundance or scarcity of the following factors in each country or region:

1) The larger the absolute size of the economy, the more efficient it is to have several urban concentrations of optimum size. This is what WS call the size of the market factor. "If the efficient level of production for a given sector is fixed, a larger national market clearly encourages a greater number of such production centers to be established in order to reduce transportation costs" (p.24).

2) The level of GDP per capita has a nonlinear relationship with the size of urban areas, where urban concentration increases first at an increasing then at a decreasing rate with the increase of GDP per capita. This nonlinear relationship between development and several other variables has been discussed by many writers such as Alonso (1980) and Amos (1988). The latter discusses the relationship between unbalanced regional growth and the level of development, which is somewhat related to the formation of urban agglomerations as they divert resources from elsewhere to grow rapidly at first then slowly with economic development.

Wheaton and Shishido (1981) rationalize this relationship by arguing that urban areas grow as a result of the growth in capital requirements of industry. Higher capital intensity implies that a larger scale is needed to produce efficiently. As fixed costs grow relative to variable costs, the efficient output of a plant grows. "This trend should hold not only in explaining differences in plant sizes across commodities, but also in explaining differences across countries in the production of a given commodity. When labor-intensive methods are used, such in developing nations, production exhibits few scale economies' (p. 23).

Although capital intensity data may not be available for all countries, note that it is highly correlated with per capita income.

This analysis of course can be extend to R&D expenditures per plant and other kinds of specialized inputs. Either way, this suggests that agglomerations might be related to per capita income non linearly, arising faster in the early take off stages of development:

> "Thus in the early rapid stages of economic development, the optimal level of production for each urban area increases faster with GNPCAP than with GNP. The result is that fewer urban areas are efficient so urban concentration increases. At the point where capital saturation starts to occur, economic development has progressively less influence on the optimum level of production for each center. The GNP, however, still increases proportionally with GNPCAP, so the country's market is now growing faster than the optimum output for each urban area. Aggregate efficiency is, therefore, improved by creating more urban areas or through spatial decentralization" (WS 1981, p.25)

3) The third factor relates to transportation cost through the interaction of area and population. A larger area is supposed to make transportation more costly and thus induces concentration, given everything else constant. On the other hand, if population increases over a fixed area, that should induce decentralization as density rises. Among the other variables, this one is the least exact from the point of view of theory since not all areas are equally inhabitable, and the population is not evenly spread over all inhabitable areas. Neither are all countries endowed with the same transportation technologies or capabilities.

4) As mentioned before, many writers emphasized the positive association between measures of education and urban concentration. Moomaw and

Shatter (1996) wonder if education alters preferences towards consumption bundles that are supplied less expensively by urban areas (p. 18). But Henderson (1988) suggests that education simply correlates strongly with the state of technology in the economy which drives firms towards urban areas.

5) The Krugman Hypothesis states that openness to trade lowers urban concentration because smaller agglomerations are now needed to supply the market since part of the consumption is imported. If imported goods can be delivered more or less at the same cost from other countries to different regions openness will foster decentralization and trade barriers will foster centralization.

At any rate, this dissertation is concerned mainly with interactions between economic growth and urban agglomerations, and thus other variables that affect urbanization are only being explored for the sake of providing the right context to study the original question under consideration. With that in mind, I regress the Ln $(U_t /L_t)$ and Ln $S_\mu$ in turn on the independent variables above to generate tables XX and XXI. First a basic urban agglomeration equation is tested against logarithms of real GDP, Ln GDP, real GDP per capita, Ln GDPPC, real GDP per capita squared, Ln $GDPPC^2$, and density. Then each of the average years of education for population over 25 deflated by the pupil teacher ratio, Ln $H_2$, or not deflated, Ln $H_t$, the sum of exports plus imports divided by GDP, Ln Open, and Ln n, the population growth rates are added consecutively.

In spite of the fact that the overall fit of the Ln $(U_t/L_t)$ was much better than that of Ln $S_\mu$, both proxies of urban agglomeration generally exhibit predictable patterns of behavior: an interesting finding here is that the nonlinear relationship between urban agglomeration and real income per capita emerges in every single specification. Urban agglomeration increases at an increasing then a decreasing rate in real income per capita as predicted by theory.

## Table XX Explaining Urban Agglomeration:

Dependent Variable: Ln $S_{\mu}$

Percentage of Population in Agglomerations > 750 thousand

63 countries at 6 five-year intervals (1960-85)

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Intercept: | - 16.5 (-6.83) | -16.46 (-6.75) | -15.42 (-6.4) | -16.12 (-6.89) | -17.0 (-7.45) |
| Ln GDP: | - 0.04 (-1.86) | - 0.03 (-1.3) | -0.048 (-1.76) | -0.054 (-2.0) | -0.05 (-1.97) |
| Ln GDPPC: | 4.44 (7.5) | 4.55 (7.58) | 4.23 (7.15) | 3.7 (6.3) | 3.76 (6.61) |
| Ln $GDPPC^2$: | -0.24 (-6.47) | -0.26 (-6.69) | -0.23 (-6.06) | -0.192 (-5.04) | -0.2 (-5.4) |
| Ln Density: | 0.063 (3.14) | 0.07 (3.5) | 0.063 (2.98) | 0.096 (4.43) | 0.089 (4.21) |
| Ln $H_2$: | | 0.13 (2.58) | 0.081 (1.6) | 0.14 (2.73) | |
| Ln $H_t$: | | | | | 0.27 (4.71) |
| Ln Open: | | | -0.086 (-2.29) | -0.092 (-2.52) | -0.086 (-2.4) |
| Ln n: | | | | 1.25 (4.68) | 1.32 (5.095) |
| Adj R-sq | .46 | .48 | .48 | .51 | .53 |
| F-Value | 82.48 | 66.98 | 56.6 | 54.57 | 59.5 |

Table XXI Explaining Urban Agglomeration Per Capita:

Dependent Variable: Ln (U/L)

Percentage of Population in Agglomerations > 750 thousand Divided by Urban Population

63 countries at 6 five-year intervals (1960-85)

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Intercept: | 3.81 (2.25 ) | 3.69 (2.14) | 4.31 (2.48) | 3.95 (2.3) | 3.64 (2.16) |
| Ln GDP: | -1.01(-59.23) | -1.0 (-57.8) | -1.02 (-51.01) | -1.02 (-51.78) | -1.02(-52.23) |
| Ln GDPPC: | 2.15 (5.19) | 2.05 (4.8) | 1.92 (4.51) | 1.67 (3.85) | 1.72 (4.08) |
| Ln $GDPPC^2$: | -0.075 (-2.84) | -0.066 (-2.41) | -0.055 (-2.01) | -0.035 (-1.27) | -0.04 (-1.52) |
| Ln Density: | 0.054 (3.83) | 0.06 (4.18) | 0.062 (4.05) | 0.078 (4.98) | 0.08 (5.18) |
| Ln $H_2$: | | -0.052 (-1.49) | -0.042 (-1.15) | -0.013 (-0.35) | |
| Ln $H_1$: | | | | | 0.044 (1.04) |
| Ln Open: | | | - 0.06 (-2.12) | -0.06 (-2.26) | -0.06 (-2.3) |
| Ln n: | | | | 0.63 (3.2) | 0.71 (3.68) |
| Adj R-sq | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 |
| F-Value | 986.281 | 746.04 | 607.3 | 535.86 | 547.25 |

Furthermore, there is a significant negative relationship between the size of the market as proxied by Ln GDP and the level of urban agglomeration. In the case of Ln ($U_t/L_t$), that relationship is consistently unitary elastic. Thus an increase of one percent in the size of GDP, decreases our measure of urban agglomeration per capita by slightly more than one percent.

Moreover the Krugman hypothesis finds empirical support here in all specifications. An increase in the degree of openness lowers urban agglomeration even though the magnitude of the coefficient is not that large.

As for population growth, an increase of one percent in the population growth rate, increases the percentage of the total population living in urban agglomerations by more than one percent, but Ln ($U_t/L_t$) increases by less than one percent, yet significantly. This should show how much of the so-called "urban bias" is simply being fueled by a population explosion in the third world.

An increase in average years of education is positively correlated with the rise of urban agglomerations as expected, but when deflated by the pupil - teacher ratio in primary school in the table below, the coefficients are negative. That finding is hot robust in different specifications and not highly significant. Thus the evidence still remains in favor of a positive correlation between education and urban agglomeration.

The only result that may be somewhat inconsistent with typical findings in the literature is the one on the coefficients of density which are always positive, highly significant and low in magnitude in all specifications. This result says that an increase in density by one percent, increases urban agglomeration by a small magnitude. Now the expected sign was negative if higher density should lower transportation cost.

Finally, to conclude this section on the interrelationships between urban agglomeration and economic growth, I ran a group of simultaneous equations with one model for economic growth and another for urban agglomeration in each run using the Two-Stage Least Squares procedure (2SLS). The urban agglomeration equation using Ln $(U_t/L_t)$ is combined consecutively with equations 4.18 (b) and 4.18 ( c) using fixed effects.

## Table XXII: Results of Simultaneous Equation Estimations/Steady State

(2SLS assuming countries are in their steady state, or in equilibrium)

Equation One: Dependent Variable: Ln (U/L)

Percentage of Population in Agglomerations > 750 thousand Divided by Urban Population

63 countries at 6 five-year intervals (1960-85)

| | (1) w/18b unrest. | (2)w/18c unrest. | (3)w/18b rest. | (4)w/18c rest. |
|---|---|---|---|---|
| Intercept: | 3.178 (1.796) | 3.178 (1.796) | 3.178 (1.796) | 3.178 (1.796) |
| Ln GDP: | -1.019 (-51.85) | -1.019 (-51.85) | -1.019 (-51.85) | -1.019 (-51.85) |
| Ln GDPPC: | 1.843 (4.178) | 1.843 (4.178) | 1.843 (4.178) | 1.843 (4.178) |
| Ln $GDPPC^2$: | - 0.05 (-1.76) | - 0.05 (-1.76) | -0.05 (-1.76) | - 0.05 (-1.76) |
| Ln Density: | 0.077 (4.819) | 0.077 (4.82) | 0.077 (4.82) | 0.077 (4.82) |
| Ln $H_t$: | 0.055 (1.277) | 0.055 (1.277) | 0.055 (1.277) | 0.055 (1.277) |
| Ln Open: | -0.062 (-2.309) | - 0.062 (-2.309) | - 0.062 (-2.309) | - 0.062 (-2.309) |
| Ln n: | 0.692 (3.556) | 0.692 (3.556) | 0.692 (3.556) | 0.692 (3.556) |
| | | | | |
| Adj R-sq | 0.91 | 0.91 | 0.91 | 0.91 |
| F-Value | 541.2 | 541.2 | 541.2 | 541.2 |

Equation Two: Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | | Restricted | |
|---|---|---|---|---|
| | (1)No Shifter | (2)W/ Shifter | (3)No Shifter | (4) W/ Shifter |
| Constant | Fixed Effects | Fixed Effects | Fixed Effects | Fixed Effects |
| t | 0.126 (13.36) | 0.113 (9.62) | 0.125 (13.69) | 0.109 (9.38) |
| Ln $H_t$ | | -0.138 (-2.45) | | -0.109 (-1.99) |
| Ln $U_t$ | | -0.397 (-2.56) | | -0.344 (-2.24) |
| $H_t$ $U_t$ | | 0.002 (4.26) | | 0.0017(3.94) |
| Ln $S_K$ | 0.227 (5.77) | 0.219 (5.50) | | |
| Ln $S_H$ | 0.143 (3.33) | 0.143 (3.49) | | |
| Ln $(n+g+\delta)$ | -0.228 (-1.25) | 0.016 (0.09) | | |
| Ln $(U_t/L_t)$ | 0.167(2.51) | 0.154 (2.38) | 0.17 (2.56) | 0.15 (2.325) |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | | 0.224 (5.77) | 0.205 (5.2) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | | 0.136 (3.28) | 0.125 (3.03) |
| | | | | |
| Adj R-squared | 0.99 | 0.99 | 0.99 | 0.99 |
| F-value | 11570.021 | 11815.116 | 11767.037 | 11870.71 |

Columns (1) and (2) include the estimates with each of 18 (b) and ( c) unrestricted. Columns (3) and (4) include the estimates with each of 18 (b) and (c ) restricted. The results are tabulated in Table XXII above. Deriving the elasticities of output with respect to physical, human, and urban capital from the coefficients of the restricted equations of columns (3) and (4) respectively, we get the following values:

| | (3) No shifter | (4)w/shifter |
|---|---|---|
| $\alpha$ | 0.165 | 0.154 |
| $\beta$ | 0.10 | 0.094 |
| $\gamma$ | 0.125 (2.572) | 0.11 (2.316) |

Table XXII indicates that results from economic growth equations above are very similar to the results when LSDV is used without simultaneous equations. The same is true for the urban concentration equations. This suggests no simultaneous equations bias in the estimation. Additionally, the elasticities of output with respect to all three kinds of capital also extremely close to those calculated under LSDV. This reinforces the results obtained earlier, and the general conclusions of this study.

Furthermore, one may redo the regressions above with LSDV and 2SLS under the assumption of disequilibrium, i.e., under the assumption that economies are converging towards the steady state. This would be done to calculate the coefficient of convergence $\lambda$ to compare the results with and without 2SLS. The results of the new regressions are below in Table XXIII.

## Table XXIII: Results of Simultaneous Equation Estimations/Disequilibrium

### (2SLS assuming no steady state; countries are in disequilibrium)

Rquation One: Dependent Variable: Ln (U/L)

Percentage of Population in Agglomerations > 750 thousand Divided by Urban Population

63 countries at 6 five-year intervals (1960-85)

| | (1) w/18b unrest. | (2)w/18c unrest. | (3)w/18b rest. | (4)w/18c rest. |
|---|---|---|---|---|
| Intercept: | 3.178 (1.79) | 3.178 (1.79) | 3.178 (1.79) | 3.178 (1.79) |
| Ln GDP: | -1.018 (-51.61) | -1.018 (-51.61) | -1.018 (-51.61) | -1.018 (-51.61) |
| Ln GDPPC: | 1.85 (4.17) | 1.85 (4.17) | 1.85 (4.17) | 1.85 (4.17) |
| Ln $GDPPC^2$: | - 0.05 (-1.76) | - 0.05 (-1.76) | - 0.05 (-1.76) | - 0.05 (-1.76) |
| Ln Density: | 0.076 (4.69) | 0.076 (4.69) | 0.076 (4.69) | 0.076 (4.69) |
| Ln $H_t$: | 0.05 (1.14) | 0.05 (1.14) | 0.05 (1.14) | 0.05 (1.14) |
| Ln Open: | -0.061 (-2.26) | -0.061 (-2.26) | -0.061 (-2.26) | -0.061 (-2.26) |
| Ln n: | 0.682 (3.48) | 0.682 (3.48) | 0.682 (3.48) | 0.682 (3.48) |
| | | | | |
| Adj R-sq | 0.91 | 0.91 | 0.91 | 0.91 |
| F-Value | 538.43 | 538.43 | 538.43 | 538.43 |

Equation Two: Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1965-85)

| | Unrestricted | | Restricted | |
|---|---|---|---|---|
| | (1)No Shifter | (2)W/ Shifter | (3)No Shifter | (4) W/ Shifter |
| Constant | Fixed Effects | Fixed Effects | Fixed Effects | Fixed Effects |
| t | 0.117 (12.43) | 0.105 (8.89) | 0.115 (12.6) | 0.1 (8.61) |
| Ln $H_t$ | | -0.11 (-2.02) | | -0.081 (-1.5) |
| Ln $U_t$ | | -0.27 (-1.75) | | -0.215 (-1.39) |
| $H_t$ $U_t$ | | 0.0017 (3.76) | | 0.0015 (3.41) |
| Ln $S_K$ | 0.23 (5.96) | 0.22 (5.6) | | |
| Ln $S_H$ | 0.15 (3.58) | 0.149 (3.60) | | |
| Ln $(n+g+\delta)$ | -0.16 (-0.89) | 0.029 (0.15) | | |
| Ln $(U_t/L_t)$ | 0.12 (1.79) | 0.107 (1.66) | 0.12 (1.85) | 0.105 (1.62) |
| Ln $(Y/L)_{T-1}$ | 0.076 (4.45) | 0.064 (3.69) | 0.074 (4.36) | 0.064 (3.69) |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | | 0.223 (5.87) | 0.204 (5.27) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | | 0.137(3.42) | 0.13 (3.21) |
| | | | | |
| Adj R-squared | 0.99 | 0.99 | 0.99 | 0.99 |
| F-value | 12053.276 | 12052.72 | 12225.104 | 12089.082 |

Deriving the elasticities of output with respect to physical, human, and urban capital from the coefficients of the restricted equations of columns (3) and (4) respectively, we get the following values in columns (1) and (2) below:

| | (1) No shifter | (2)w/shifter | (3) No shifter | (4) w/shifter |
|---|---|---|---|---|
| $\lambda$ | 0.104 (11.31) | 0.109 (10.03) | Steady State | Steady State |
| $\alpha$ | 0.17 | 0.16 | 0.165 | 0.154 |
| $\beta$ | 0.11 | 0.10 | 0.10 | 0.094 |
| $\gamma$ | 0.094 (2.00) | 0.083 (1.72) | 0.125 (2.572) | 0.11 (2.316) |

Columns (3) and (4) above are the same as columns (3) and (4) from the previous page where the elasticities where derived assuming the steady state. The estimated values obtained in columns (1) and (2) compare favorably with the values obtained in columns (3) and (4), as well as with the results of Table XIX where $\alpha$, $\beta$, $\gamma$, and $\lambda$ where obtained under the assumption of convergence (no steady state) but without 2SLS. The values of $\lambda$ there where .104 and .11 respectively. However, the t-values of the output elasticity with respect to urban capital $\gamma$, where lower there than the t-values for $\gamma$ under 2SLS. Generally speaking however, we can say that overall the results above imply that the elasticities obtained under different specifications gravitate towards similar values.

*Implication Three: Country effects*

Using the regressions developed under the assumption of disequilibrium from table XIX, we recover estimates of the country effects for both of the cases with and without a shifter. First we report the estimates in the table below, then we report them as normalized rankings on a scale of 0 to 100 showing where a given country lies between the highest scoring country (U.S.A with a score of 100) and the lowest (Tanzania with a score of 0).

To normalize country effects, using the country effects from regression 7.4b (with shifter), all estimates were first divided by the minimum-value country effects which was for Tanzania equal to 7.66. Then one was subtracted from that ratio so we were left only with deviation from the minimum country effect. Those country deviations from the minimum were then curved so the highest deviation was equal to 100, and the lowest to zero. This scaling procedure was generated by multiplying each of the deviation by the constant 288, which is the multiple needed to change the maximum deviation of the United States into 100. An example is provided beneath Table XXIV below.

The implications of the raw and normalized country effects will be discussed afterwards.

## Table XXIV: Raw Country Effects Ln $A_0$ Alphebatically

| Country | No Shifter | Shifter |
|---|---|---|
| 1.Algeria | 8.22 | 8.99 |
| 2.Argentina | 8.96 | 9.58 |
| 3.Australia | 9.53 | 9.69 |
| 4.Austria | 9.16 | 9.83 |
| 5.Bangladesh | 8.1 | 8.95 |
| 6.Belgium | 9.41 | 10.13 |
| 7.Bolivia | 7.92 | 8.69 |
| 8.Brazil | 8.67 | 9.5 |
| 9.Cameroon | 7.7 | 8.52 |
| 10.Canada | 9.64 | 10.14 |
| 11.Chile | 8.63 | 9.34 |
| 12.Columbia | 8.42 | 9.21 |
| 13.Congo | 7.79 | 8.77 |
| 14.Costa Rica | 8.31 | 8.99 |
| 15.Denmark | 9.86 | 9.32 |
| 16.Dominican Rep | 7.97 | 8.71 |
| 17.Ecuador | 8.15 | 8.88 |
| 18.Finland | 9.23 | 9.87 |
| 19.France | 9.52 | 10.31 |
| 20.Germany | 9.53 | 10.04 |
| 21.Ghana | 7.64 | 8.41 |

| | | |
|---|---|---|
| 22.Greece | 8.7 | 9.24 |
| 23.Guatemala | 8.3 | 9.18 |
| 24.Haiti | 7.67 | 8.49 |
| 25.Hong Kong | 8.83 | 9.15 |
| 26.India | 7.62 | 8.47 |
| 27.Indonesia | 7.76 | 8.59 |
| 28.Iran | 8.84 | 9.68 |
| 29.Iraq | 9.09 | 9.89 |
| 30.Ireland | 8.69 | 9.25 |
| 31.Italy | 9.32 | 10.07 |
| 32.Japan | 9.24 | 9.87 |
| 33.Jordan | 7.93 | 8.71 |
| 34.Malaysia | 8.36 | 9.1 |
| 35.Mexico | 9.06 | 9.87 |
| 36.Mozambique | 7.77 | 8.62 |
| 37.Netherlands | 9.47 | 10.21 |
| 38.New Zealand | 9.37 | 9.94 |
| 39.Nicaragua | 8.1 | 8.89 |
| 40.Pakistan | 7.8 | 8.65 |
| 41.Panama | 8.12 | 8.73 |
| 42.Peru | 8.43 | 9.19 |
| 43.Philippines | 8.12 | 8.87 |
| 44.Portugal | 8.53 | 9.35 |
| 45.Rep.(South) Korea | 8.09 | 8.62 |

| | | |
|---|---|---|
| 46.Senegal | 7.83 | 8.64 |
| 47.Singapore | 8.4 | 8.98 |
| 48.Spain | 9.2 | 9.99 |
| 49.Sudan | 7.89 | 8.69 |
| 50.Sweden | 9.53 | 10.26 |
| 51.Syria | 8.43 | 9.25 |
| 52.Thailand | 8.02 | 8.76 |
| 53.Tunisia | 7.97 | 8.75 |
| 54.Turkey | 8.38 | 9.22 |
| 55.Uganda | 7.35 | 8.17 |
| 56.U.K. | 9.51 | 10.19 |
| 57.U.R.Tanzania | 6.85 | 7.66 |
| 58.U.S.A. | 10.00 | 10.32 |
| 59.Uruguay | 8.61 | 9.27 |
| 60.Venezuala | 9.36 | 10.19 |
| 61.Yugoslavia | 8.57 | 9.32 |
| 62.Zambia | 7.47 | 8.22 |
| 63. Zimbabwe | 7.61 | 8.42 |

*Example:*

To generate normalized values from the raw country effects for the United States for example, we divide its intercept of 10.32 by that of Tanzania of 7.66. The quotient is equal to 1.347. Subtracting 1 from that leaves a deviation from the minimum of 0.347. Since that is the maximum deviation in the sample, we want it equal to 100 which means we have to multiply it by 288. Thus multiplying each country deviation by 288 yields the "curved" values in the table below.

Table XXV: Country Effects Ln $A_0$ Normalized and by Rank

(Country Effects are ordered from highest to lowest)

| Country | Score | Country | Score | Country | Score |
|---|---|---|---|---|---|
| 1.U.S.A | 100 | 22.Brazil | 69.5 | 43.Congo | 41.9 |
| 2.France | 99.6 | 23.Portugal | 63.6 | 44.Thailand | 41.5 |
| 3.Sweden | 97.7 | 24.Chile | 63.1 | 45.Tunisia | 41.2 |
| 4.Netherlands | 96 | 25.Yugoslavia | 62.4 | 46.Panama | 40.6 |
| 5.U.K. | 95.3 | 26.Uruguay | 60.8 | 47.Dominican Rep | 39.7 |
| 6.Venezuala | 94 | 27.Ireland | 60 | 48.Jordan | 39.6 |
| 7.Canada | 93.3 | 28.Syria | 59.8 | 49.Sudan | 38.9 |
| 8.Belgium | 93.2 | 29.Greece | 59.7 | 50.Bolivia | 38.8 |
| 9.Italy | 90.6 | 30.Turkey | 58.7 | 51.Mozambique | 37.5 |
| 10.Germany | 89.4 | 31.Columbia | 58.3 | 52.Pakistan | 37.3 |
| 11.Spain | 87.6 | 32.Peru | 57.5 | 53.Senegal | 36.8 |
| 12.NewZealand | 86 | 33.Guatemala | 57.3 | 54.South Korea | 36.1 |
| 13.Iraq | 83.9 | 34.Hong Kong | 56.3 | 55.Indonesia | 35.2 |
| 14.Finland | 83.4 | 35.Malaysia | 54.4 | 56.Cameroon | 32.3 |
| 15.Mexico | 83.4 | 36.Algeria | 50 | 57.Haiti | 31.4 |
| 16.Japan | 83.3 | 37.Singapore | 49.9 | 58.India | 30.7 |
| 17.Denmark | 83 | 38.Costa Rica | 49 | 59.Ghana | 28.5 |
| 18.Austria | 81.8 | 39.Bangladesh | 48.8 | 60.Zimbabwe | 28.5 |
| 19.Australia | 76.4 | 40.Nicaragua | 46.3 | 61.Zambia | 21 |
| 20.Iran | 76 | 41. Ecuador | 46 | 62.Uganda | 19.1 |
| 21.Argentina | 72.4 | 42.Philippines | 45.4 | 63.U.R.Tanzania | 0.0 |

The country effects in all models were significant. Several observations regarding normalized results are relevant. First the model has been quite successful in explaining the economic growth of the so-called Asian tigers. Singapore, Hong Kong, and South Korea have relatively low country effects after accounting for saving, labor, education, and urbanization.

By the same token the countries at the top of the list have the highest country effects because the variables in the model were insufficient to explain their standard of living. If we deem country effects to account for technology, culture, institutions, natural resource endowments and preferences, then to that extent country effects have something inherently capable of raising the standard of living above and beyond what normal saving, hard work, education and location can.

One difference between the rankings that Nazrul Islam gave different countries and our country effects is that he put the United States, Canada, and Hong Kong as the top three countries. In our case, the United States is still first, Canada dropped to number seven, and Hong Kong dropped to number 34. Also Nazrul Islam puts the United Kingdom and France in right after the first group which is a result we confirm, but he places Singapore with them up there, whereas Singapore drops to number 37 in our list. Sweden and the Netherlands move up from the third group with Nazrul Islam to the top in our sample. To the extent that urbanization is important, it is not surprising that excluding it in the model reduces Hong Kong and Singapore's country effects.

Our results also differ from Islam's in the rise of Venezuela into the top category. Another difference is the relatively large country effects for Mexico, Iraq, and Iran. Since the country effects capture increases in income that are not explained by the variables in the model, it is possible that since the regressions were run for the period 1960-85, and since that period included an oil boom, that in those countries the oil boom caused a significant rise in the country effects. On the other hand Islam used these same years also so this may not be the reason why these countries have such high country effects. Either way the fact remains that the importance of country effects has been established, and thus exploring their determinants might be one direction to pursue for future research.

*Conclusion:*

The results of this dissertation highlight the importance of intangible inputs such as human and urban capital in addition to the traditional determinants of the Solow model. As inputs in the aggregate production function for the economy as a whole, these effects might be viewed as individual externalities. On the other hand, the results emphasize the relevancy of human and urban variables in economic growth as inputs and as shifters of the production function itself.

The estimated output elasticities with respect to physical, human, and urban capital, $\alpha$, $\beta$, and $\gamma$ respectively are within a reasonable range and are statistically significant. Econometric tests indicated that the LSDV estimator is preferred in analyzing economic growth problems when the MRW framework is expanded or augmented to include the input and shifter effects of human and urban capital together.

The interrelationships between urban agglomeration and economic growth are complex and varied. Both of the urban agglomeration indices used here, urban agglomeration and urban agglomeration per capita, behave in general in accordance with the predictions of urban economics: Economic growth affects both urban agglomeration indices in a nonlinear fashion. First economic growth causes them to increase at an increasing then at a decreasing rate. The size of GDP itself causes urban agglomeration indices to decrease also in accordance with theory.

On the other hand, urban agglomeration indices as independent variables in the economic growth equations yield knowledge spillovers, i.e., externalties , which make employment and incomes in cities grow. Dynamic externalities give rise to economic growth through their impact on cities. The Rauch is also confirmed in the model. The geographic concentration of human capital increases the standard of living of nations, above and beyond the separate contributions of human and urban capital.

One interesting finding of this dissertation is the result that the output elasticities with respect to physical capital, are much lower than any obtained elsewhere. This results in higher rates of convergence than any other study has found so far. Countries bridge the gap between actual and steady state income in less than a decade, using the expanded model. Moreover, countries converge to different steady states conditional on the rates of growth of tangible and intangible inputs in that country. Also countries have different intercepts to account for the effects of technology, culture, institutions, and the like. But once intangible inputs are accounted for, many countries whose growth was previously mysterious, become normal growth countries and in some cases below average. Hard work, saving, education, and urbanization do pay.

In conclusion we note that a burgeoning city and a growing economy partake in some of the same processes such as technological innovation, quantitative growth in terms of income and employment, as well as social and political transformation. Through these processes the economy and the city have been historically intertwined. It was the transition from a nomadic to an agricultural existence, then along a parallel path from primitive urban settlement to urban concentration to urban agglomeration that defined in the collective human unconsciousness the meaning of the word civilization. Then if that concept is to at all be associated with advancement in the material and cultural standard of living, urbanization and economic (and other kinds of) growth become synonymous. Indeed according to one point of view, "that modern precept stating that development implies a continuous (and positive) change upwards, emanated from the experience of urbanization itself" (Moussa 1998, p.53). The same writer emphasizes: "The discoveries of archeologists in ancient Egypt and Mesopotemia, as well as ancient India and China, didn't only bewilder scientists and tourists for the primevality of the phenomenon of inhabiting cities, but also for literally uncovering the role of cities in the progress of civilization" (Ibid p.50).

Shakespeare once wondered through one of the characters in his plays: “What is the city, but the people?” (The Tragedy of Coriolanus, act 111, sc.1, line 198).

On the other hand, the nineteenth century thinker Max Weber wrote in his The City that the city is its market (Weber 1962, pp.72-73). [Both references above were cited in Moussa 1998].

Therefore one can perhaps illustrate the essence of this dissertation with the idea that if both Shakespeare and Weber were right, then putting people and markets together in the confines of a system of cities ends up creating through a thousand channels a very powerful engine of economic growth.

# BIBLIOGRAPHY


Acs, Z.J., Audretsch, D.B., and Feldman, M.P., "Real Effects of Academic Research: Comment", American Economic Review, v82n1, pp. 363-367, March 1992.

----------, ------------------, and ------------------, "R&D Spillovers and Innovative Activity", Managerial and Decision Economics, vol.15, pp.131-138, 1994.

Adelman, I., Theories of Economic Growth and Development, fouth edition, Stanford University Press, 1967.

Ades, A., and Glaeser, E., "Trade and Circuses: Explaining Urban Giants", The Quarterly Journal of Economics, pp.195-227, February 1995.

Alonso, W., "Five Bell Shapes in Development", Papers and Proceedings of the Regional Science Association , 45, pp.5 -16., 1980.

Alwosabi, M., "The Impact of Economic, Political, and International Factors on Urban Primacy", An Oklahoma State University Dissertation, 1996, Major Advisor: Dr. Ron Moomaw.

Amos, O. M., "Unbalanced Regional Growth and Regional Income Inequality in the Latter Stages of Development", Regional Science and Urban Economics, 18, pp.549-566, 1988.

Anonymous, The Economist, May $25^{th}$, 1996, pp.23-25.

Arrow, K.J., "The Economic Implications of Learning by Doing", Review of Economic Studies, 29, pp. 155-73, June 1962.

Barro-Lee Data Set 1994.

Barro, R., "Economic Growth in a Cross-Section of Countries", NBER Working Papers Series # 3120, September 1989.

-----------, and Sala-i-Martin, X., "Economic Growth and Convergence across the United States", NBER Working Papers Series # 3419, August 1990.

-----------, ------------------------, Economic Growth, McGraw-Hill, New York, 1995.

-----------, "Inflation and Growth", Federal Reserve Bank of St. Louis Review, v78n3, pp.153-169, May/June 1996.

Becker, G., Human Capital, Columbia University Press for the National Bureau of Economic Research, 1964.

Beeson, P., and Montgomery, E., "The Effects of Colleges and Universities on Local Labor Markets", Review of Economics & Statistics, v75n4, pp.753-761, November 1993.

Benhabib, J., and Spiegel, M.M., "The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data", Journal of Monetary Economics, 34, pp.143-173, 1994.

Chiang, A., Fundamental Methods of Mathematical Economics, third edition, McGraw-Hill Book Company, New York, 1984.

Denison, E. F., The Sources of Economic Growth in the United States and the Alternatives Before Us, Committee for Economic Development, New York, 1962.

Domar, E.D., "Capital Expansion, Rate of Growth, and Employment", Econometrica, pp. 137-47, April, 1946.

De Gregorio, J., "Economic Growth in Latin America", Journal of Development Economics, 29, pp. 59-84,1992.

Edgmand, M., Macroeconomics: Theory and Policy, third edition, Prentice-Hall, New Jersey, 1987.

Fisher, R.C., State and Local Public Finance, Scott, Foresman, and Company, Glenview, Illinois, 1988.

Glaeser, E., , Scheinkman, J.A., Shleifer, A., Kallal, H., "Growth in Cities", Journal of Political Economy, v100n6., pp.1126-1152, 1992.

------------, ----------------------, ---------------, "Economic Growth in a Cross-Section of Cities", Journal of Monetary Economics, 36, pp.117-143, 1995.

Greene, W., Econometric Analysis, second edition, Macmillan Publishing Company, New York, 1993.

Harrod, R.F., Towards a Dynamic Economics, Mac Millan & Co. Ltd., London, 1948.

Helliwell, J.F., "Empirical Linkages Between Democracy and Economic Growth", NBER Working Papers Series # 4066, May 1992.

Henderson, J.V., "Efficiency of Resource Usage and City Size", Journal of Urban Economics, 19, pp.47-60, January 1986.

Islam, N., "Growth Empirics: A Panel Data Approach", Quarterly Journal of Economics, v110n4., pp.1127-1170, November 1995.

Jacobs, J., The Economy of Cities, Random House, New York 1969.

--------------, Cities and the Wealth of Nations: principles of Economic Life , Rndom House, New York, !984.

Judge, G., Hill, R.C., Griffiths, W.E., Lutkepohl, H., and Lee, T., Introduction to the Theory and Practice of Econometrics, John Wiley & Sons, 1988.

Kennedy, P., A Guide to Econometrics, third edition, the MIT Press, Cambridge, Massachusetts, 1996.

King, R. G., and Rebelo, S.T., "Transitional Dynamics and Economic Growth in the Neoclassical Model", NBER Working Papers Series #3185, November 1989.

Kmenta, J., Elements of Econometrics , second edition, MacMillan Publishing Company, New York, 1986.

Lowry, P., "Firm Location: A Better Proxy for Industry Reliance on Social Capability", Eastern Economic Journal, (Forthcoming).

Lucas, R. E., "On the Mechanics of Economic Development", Journal of Monetary Economics, 22, pp.3-42, 1988.

--------------, "Why Capital Doesn't Flow from Rich to Poor Countries?", AEA Papers and Proceedings, v80n2, pp.92-96, May 1990.

Mankiw, G., Romer, D., and Weil, D., "A Contribution to the Empirics of Economic Growth", NBER Working Paper Series # 3541, December 1990.

Marshall, A., Principles of Economics , Macmillan, London, 1890.

Mills, E.S., and Hamilton, B.W., Urban Economics, fourth edition, Scott, Foresman and Company, Glenview, Illinois, 1989.

Moomaw, R., "Productivity and City Size: A Critique of the Evidence", The Quarterly Journal of Economics, 96, pp.675-688, 1981.

------------, "Agglomeration Economies: Localization or Urbanization?" , Urban Studies, 25, pp.150-161, 1988.

---------------, and Shatter, A., "Urbanization and Economic Development: A Bias Towards Large Cities?", Journal of Urban Economics ,40, pp.13 -37, 1996.

---------------, and Alwosabi, M., "Urban Primacy: An Empirical Analysis of Competing Explanations", A draft presented at the annual meeting of the Regional Science Association , Buffalo, New York, November 1997.

---------------, and ----------------, "Urban Primacy or Main-City Size: Does it Matter?" , A Draft, 1997.

Moussa, M. Y., "The Arab City and Development", Al-Moustaqbal Al-Arabi (A Refereed Social Science Monthly in Arabic ISSN 1024-9834), pp. 49-67, February 1998.

Nakamura, R., "Agglomeration Economies in Urban Manufacturing Industries; A Case of Japanese Cities', Journal of Urban Economics, 17, 108-124, 1985.

Penn World Tables Data Set, Mark 5.6.

Pindyck, R., and Rubinfeld, D., Econometric Models and Economic Forecasts , second edition, McGraw-Hill Book Company, New York, 1981.

Rauch, J., "Productivity Gains from the Geographic Concentration of Human Capital: Evidence from the Cities", Journal of Urban Economics, 34, pp.380-400, 1993.

Romer, P., "Increasing Returns and Long-Run Growth", Journal of Political Economy , pp.1002-1037, October 1994.

Sachs, J.D, Warner, A.M., "Natural Resource Abundance and Economic Growth", NBER Working Papers # 5398, December 1995.

Schultz, T.W., The Economic Value of Education, Columbia University Press, 1963.

Shakespeare, W., The Tragedy of Coriolanus.

Shatter, A., "Urbanization as a Factor in Economic Growth", excerpts from Oklahoma State University Doctoral Dissertation, 1992. Major Advisor: Ron Moomaw.

Smith, A., The Wealth of Nations, Random House, New York, 1937 [1776].

Solow, R., "A Contribution to the Theory of Economic Growth", Quaterly Journal of Economics, 70, pp. 65-94, February 1956.

Stein., H., and Foss., M., The New Illustrated Guide to the American Economy, second edition, The American Enterprise Institute, Washington, D.C., 1995.

Swan, T., "Economic Growth and Capital Accumulation",

Thurow, L., Head to Head: The Coming Economic Battle Among Japan, Europe and America, Morrow and Company Inc., 1992.

United Nations, World Urbanization Prospects: The 1994 Revision, New York, 1995.

United Nations, Statistical Yearbook of UNESCO, United Nations Educational, Scientific, and Cultural Organization, 1994.

United Nations, Demographic Yearbook, New York, Department of International Economic and Social Affairs, (Different Issues).

United Nations, International Trade Statistics Yearbook, New York, (Different Issues).

Weber, J., Mathematical Analysis: Business and Economic Applications, third edition, Harper & Row Publishers, Inc., New York, 1976.

Weber, M., The City, translated and edited by Don Martindale and Gertrud Neuwirth, A Collier Burk Publication, New York, 1962.

Wheaton,W., and Shishido, H, "Urban Concentration, Agglomeration Economies, and the Level of Economic Development", Economic Development and Cultural Change, vol. 30, pp.17-30, 1981.

World Bank, World Tables, 1995.

# APPENDIX: RANDOM EFFECTS MODELS

*Results from the Random Effects Model:*

Even though Nazrul Islam argued against a random effects model on theoretical basis, we estimate both restricted and unrestricted versions of Solow's model with and without human capital using REM for the sake of making comparisons with the results above.

Table VII: Estimation of the Solow Model W/ Random Effects

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | Restricted |
|---|---|---|
| Constant | 9.36 (25.19) | 8.62 (50.1) |
| t | 0.11 (19.03) | 0.12 (21.17) |
| Ln $S_K$ | 0.27 (7.22) | |
| Ln $(n+g+\delta)$ | - 0.68 (-3.83) | |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | 0.29 (7.7) |
| | | $\alpha = 0.22$ |
| Adj R-sq | 0.6 | 0.59 |
| Hausman Test | 25.32 | 21.4 |
| (p- value) | 0.0000 | 0.0000 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

So we see here that a random effects model is rejected in favor of the fixed effects based on the Hausman test. Nevertheless, the implied $\alpha$ of 0.22 is reasonable.

For the sake of making comparisons, I estimate MRW's model with random effects, both in restricted and unrestricted forms to obtain:

Table VIII: Estimation of MRW Model W/ Random Effects

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | Restricted |
|---|---|---|
| Constant | 9.69 (25.02) | 9.39 (34.4) |
| t | 0.11 (19.96) | 0.11 (17.61) |
| Ln $S_K$ | 0.27 (7.24) | |
| Ln $S_H$ | 0.14 (3.3) | |
| Ln $(n+g+\delta)$ | - 0.61 (-3.51) | |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | 0.28 (7.6) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | 0.15 (3.68) |
| | | $\alpha = 0.19$ |
| | | $\beta = 0.1$ |
| Adj R-sq | 0.62 | 0.62 |
| Hausman Test | 29.00 | 26.5 |
| (p-value) | 0.0000 | 0.0000 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

Again the Hausman test favors the fixed effects model. Nevertheless, the production function parameters are quite reasonable. Similar results obtain when urbanization is added as seen in Tables XVI, XVII, and XVIII. Note especially that the elasticity of output with respect to urban capital is significant there.

## Table XVI: Estimation of Equation 4.18 (c) with Random Effects:

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | | Restricted | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Constant | 10.6 (18.64) | 10.75 (18.26) | 10.72 (20.14) | 10.72 (19.6) |
| t | 0.09 (8.57) | 0.077 (6.78) | 0.087 (8.51) | 0.076 (6.84) |
| Ln $H_1$ | -0.095 (-1.8) | | -0.085 (-1.66) | |
| Ln $H_2$ | | 0.03 (0.69) | | .03 (0.71) |
| Ln $U_t$ | -0.46 (-3.42) | -0.41 (-2.95) | -0.45 (-3.45) | -0.422 (-3.09) |
| $H_t$ $U_t$ | 0.0025 (6.15) | 0.002 (5.06) | 0.0025 (6.31) | 0.0021 (5.31) |
| Ln $S_K$ | 0.25 (6.42) | 0.22 (5.65) | | |
| Ln $S_H$ | 0.15 (3.63) | 0.16 (3.88) | | |
| Ln $(n+g+\delta)$ | -0.3 (-1.69) | -0.42 (-2.34) | | |
| Ln $(U_t / L_t)$ | 0.087 (1.85) | 0.095 (2.02 ) | 0.085 (1.82) | 0.092 (2.01) |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | | 0.245 (6.46) | 0.22 (5.8) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | | 0.15 (3.65) | 0.16 (4.1) |
| | | | $\alpha$ = .17 | .16 |
| | | | $\beta$ = .11 | .12 |
| | | | $\gamma$ = .061 | .067 |
| R-sq | .66 | .65 | .66 | .65 |
| Hausman Test | 25.22 | 23.44 | 22.5 | 22.18 |
| (p-value) | 0.0014 | 0.0028 | 0.0021 | 0.0024 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

## Table XVIII: Estimation of Equation 4.19 (c) with Random Effects:

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

| | Unrestricted | | Restricted | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Constant | 10.28 (19.45) | 10.47 (19.19) | 10.54 (21.34) | 10.56 (21.06) |
| t | 0.07 (7.4) | 0.058 (5.5) | 0.07 (7.27) | 0.057 (5.5) |
| Ln $H_1$ | -0.13 (-2.5) | | -0.11 (-2.18) | |
| Ln $H_2$ | | 0.022 (0.5) | | 0.027 (0.62) |
| Ln $U_t$ | -0.53 (-3.96) | -0.48 (-3.4) | -0.49 (-3.8) | -0.47 (-3.5) |
| $H_t$ $U_t$ | 0.0025 (6.28) | 0.002 (5.07) | 0.0024 (6.19) | 0.002 (5.12) |
| Ln $S_K$ | 0.24 (6.28) | 0.21 (5.32) | | |
| Ln $S_H$ | 0.13 (3.22) | 0.16 (3.65) | | |
| Ln $(n+g+\delta)$ | -0.3 (-1.7) | -0.46 (-2.56) | | |
| Ln $S_\mu$ | 0.18 (2.91) | 0.17 (2.72) | | |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | | 0.23 (6.14) | 0.21 (5.33) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | | 0.126 (3.06) | 0.15 (3.66) |
| Ln $S_\mu$ – Ln $(n+g+\delta)$ | | | 0.158 (2.7) | 0.16 (2.76) |
| | | | $\alpha$ = .15 | .13 |
| | | | $\beta$ = .085 | . 1 |
| | | | $\gamma$ =.11 | .11 |
| R-sq | .66 | .65 | .66 | .65 |
| Hausman Test | 27.86 | 25.55 | 26.89 | 25.08 |
| (p-value) | 0.0005 | 0.0013 | 0.0003 | 0.0007 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

## Table XXVI: Estimation of Equations 4.18(b)& (c) with Fixed Effects:

Dependent Variable: log of Real GDP per Capita

63 countries at 6 five-year intervals (1960-85)

Urban capital $U_t$ is redefined as total population in urban agglomerations, and $U_t/L_t$ = (metropop)$^2$

| | Unrestricted | | Restricted | |
|---|---|---|---|---|
| | (1) No Shifter | (2)W/Shifter | (3)No Shifter | (4) W/Shifter |
| Constant | fixed effects | fixed effects | fixed effects | fixed effects |
| t | 0.116 (17.4) | 0.104 (8.26) | 0.116 (17.85) | 0.1 (8.11) |
| Ln $H_t$ | | -0.936 (-1.72) | | -0.074 (-1.4) |
| Ln $U_t$ | | -0.104 (-1.21) | | -0.095 (-1.11) |
| $H_t U_t$ | | 0.002 (5.29) | | 0.002 (5.09) |
| Ln $S_K$ | 0.23 (5.94) | 0.23 (5.84) | | |
| Ln $S_H$ | 0.106 (2.46) | 0.111 (2.62) | | |
| Ln $(n+g+\delta)$ | -0.349 (-1.93) | -0.053 (-0.29) | | |
| Ln $(U_t/L_t)$ | 0.097 (1.97) | 0.141 (2.16) | 0.097 (1.98) | 0.14(2.14) |
| Ln $S_K$ – Ln $(n+g+\delta)$ | | | 0.23 (6.05) | 0.219 (5.64) |
| Ln $S_H$ – Ln $(n+g+\delta)$ | | | 0.107 (2.55) | 0.097 (2.35) |
| | | | $\alpha$ = .174 | .166 |
| | | | $\beta$ = .082 | .088 |
| | | | $\gamma$ = .072 (1.97) | .105 (2.13) |
| Adj R-sq | .99 | .99 | .99 | .99 |
| F- Value | 251.779 | 107.4189 | 319.208 | 120.036 |

Note: T-Values are in parentheses. Estimates are rounded up to the nearest decimal.

Note how close the estimates of $\alpha$,$\beta$, and $\gamma$ are compared to the case where the definition of U/L is different. This is especially true for column (4) estimates where a shifter is included, even though the shifter itself there is less significant than before.

# VITA

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Doctor of Philosophy

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